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GEOLOGY OF THE BLACKBUTTE MERCURY MINE,  
LANE COUNTY, OREGON

by

Robert E. Derkey

B.A., University of Minnesota, Duluth, 1965

Presented in partial fulfillment of the  
requirements for the degree of

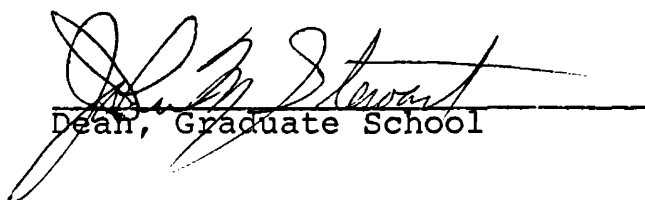
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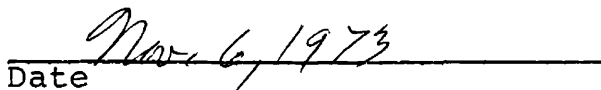
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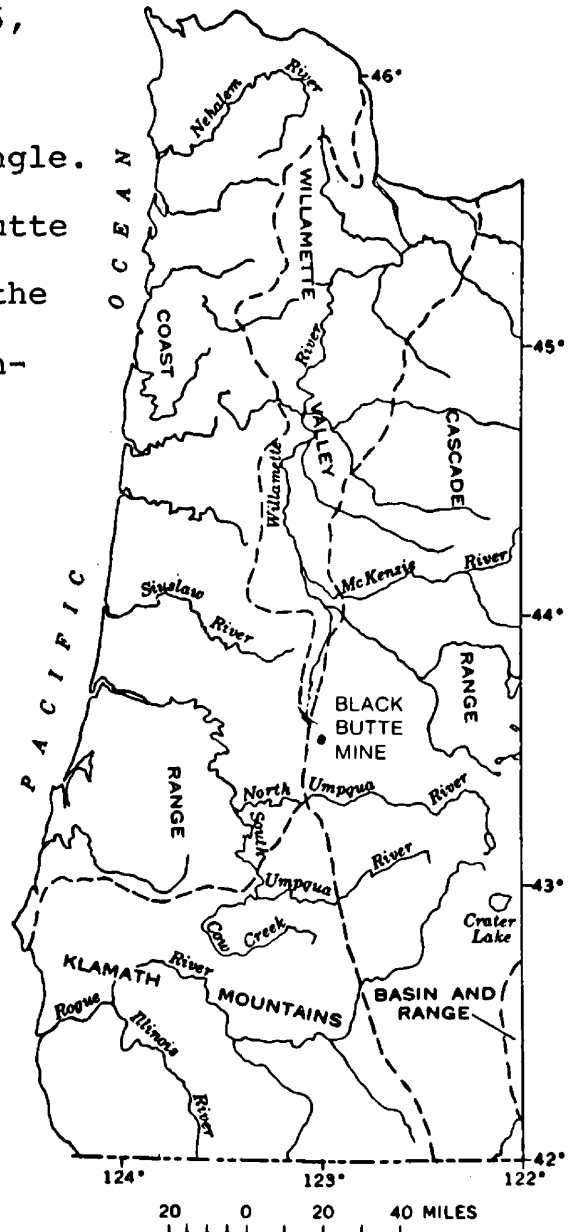
## Chapter 1

### INTRODUCTION

#### Location

The Blackbutte mine is located 17 miles south of Cottage Grove, Lane County, Oregon, on London Road. The property is located in section 16, T23S, R3W of the 15 minute U.S. Geological Survey, Anlauf Quadrangle. The mine, which is in the Blackbutte mercury district, is located on the north slope of the Calapooya Mountains, a part of the western Cascades province. Included in the district in addition to the Blackbutte mine, are the Woodard prospect and the Hobart Butte prospect.

Figure 1. Geomorphic provinces and Blackbutte mine location map (after Dicken, 1950, and Hoover, 1963).



## Purpose and Scope of Investigation

The main objectives were to describe in more detail the accessible underground workings at the Blackbutte mine. The fieldwork was primarily done on the recent workings of the 900, 1100 and 1200 levels. Examination of the upper levels was accomplished where accessible and the results agree with previous work. The aspects covered include, (1) petrologic examination of the host rocks, (2) mineralogy of the ore and gangue minerals, and (3) a detailed description of the hydrothermal alteration with established zoning characteristics.

## Previous Work

The first detailed study of the Blackbutte mine was by Wells and Waters in their report Quicksilver in Southwestern Oregon (1934). The next report was by Schutte, Quicksilver in Oregon (1938). During the intense exploration efforts of World War II, Waters (1943 and 1945) completed studies which outlined the merits of re-opening the mine. A description of the deposit and the results of a drilling program were outlined in these reports. A brief summary of previous investigations was published by Brooks in 1963.

In addition to a description of the geology in the vicinity of Black Butte by Wells and Waters (1934), a comprehensive report and geologic map of the Anlauf Quadrangle was completed by Hoover (1963). This latter

report covers the stratigraphy and lithologic characteristics of the host Fisher formation. Wells and Waters (1935) also published descriptions of the intrusive rocks of the area.

### History and Production

The Blackbutte mine, Oregon's second largest mercury producer, was discovered by S. P. Garoutte in 1890 (Brooks, 1963). Little was done on the property until 1897 when the mine was taken over by the Black Butte Quicksilver Mining Company. By 1908, under the direction of W. B. Dennis, 15,000 feet of development work had been done on the 100, 200, 300 and 400 foot levels. It was during this period that the richest ores at Black Butte were mined. Some veinlets three inches or more in width were found during the present study on these levels indicating the wealth of the earlier mining days.

The mine was closed from 1909 to 1916 due to the lowered mercury prices but was opened again during World War I in response to wartime demands for the metal. The mine was inoperative from 1919 to 1927 when it was purchased by the present property owners, Quicksilver Syndicate. By 1929 two 4 by 60 foot rotary kilns were in operation, one of which was in use in 1969. The Quicksilver Syndicate operated the mine continuously until 1942 despite the low grade of ore, a feat attributed to the efficient operation and the relative ease of mining.

The mine was reopened again during 1956 and 1957 under lease of the Mercury and Chemicals Corporation. They explored and developed ore from the 900 and 1100 foot levels. The mine was closed again until 1964 when American Mercury Corporation obtained a lease and operated it until 1966 when Black Butte Mining, Incorporated took over the lease. The mine was closed again in 1969 and has been dormant since then because of depressed mercury prices due to substitution and recycling in apparent response to the environmental problems encountered with the metal. Total recorded production of the mine prior to re-opening in 1964 was 16,074 flasks.

#### Topography and Climate

Black Butte lies at the southern extremity of the Willamette Valley near the imperceptible merging of the Cascade and Coast Ranges. The butte rises 1600 feet above the adjacent valley floor and is marked at its crest by bold ribs of silicified rocks. The division between the Cascade and Coast Ranges in this vicinity is based upon changes in geology rather than any physiographic features. The mine is within part of the Western Cascades province.

Near the crest of the butte numerous sheet-like masses of silicified andesite and andesite tuff, some of them over 100 feet high, are found. These apparently were produced by hydrothermal solutions coming up along the fault zone.

The silicified masses being more resistant to weathering, are left as erosional remnants.

Heavy underbrush combined with mine waste and steep unstable slopes of the butte hinder local exploration. However, several cuts from the numerous roads have given a clue to the extent of hydrothermal alteration of the country rocks.

The climate of the Black Butte area is temperate and moist, characterized by warm dry summers and cool winters with abundant rain and snow. Records of the U.S. Weather Bureau for a ten year period beginning in 1943 show the average precipitation at Drain, located 15 miles northwest of Black Butte, was 50.1 inches with an average temperature of 39.5° in January and 68.2° in July (Hoover, 1963).



## Chapter 2

### STRATIGRAPHY

Rock units of the southwestern Oregon mercury area as described by Hoover (1963), Brooks (1963), and Wells and Waters (1934) include Paleozoic and Mesozoic rocks of the Klamath Mountains, Tertiary marine clastics of the Coast Range, and Tertiary volcanic and pyroclastic rocks of the western Cascades. The Black Butte deposit is located in the Fisher formation of Eocene-Oligocene age in the western Cascades near the contact with Coast Range marine sediments.

#### Pre-Tertiary Rocks

A small outcropping of Paleozoic quartz-epidote-chlorite schists plus some mica and graphitic schists is found along the California border. Unconformably above these rocks is a series of Triassic and Jurassic mafic volcanic and clastic sedimentary units. Included are the Applegate group and the Dothan, Rogue and Galice formations. They were folded and metamorphosed during the Jurassic Nevadan orogeny. Post-Nevadan conglomerates and sandstones include the Myrtle group and the Hornbrook formation.

During the late Jurassic, tabular masses of peridotite and serpentized peridotite were intruded. They are commonly found along bedding planes, unconformities and faults. In California many of the quicksilver deposits are associated with this type of ultramafic body, the cinnabar usually being found near the contact with the surrounding country rock. Although there are deposits associated with peridotites in southwestern Oregon, they have no recorded production (Brooks, 1963). In addition to these ultramafic bodies, intrusives of late Jurassic and early Cretaceous age ranging from granite to diorite, are found in the Klamath Mountains.

Mercury mineralization is known from most of the Mesozoic units (Brooks, 1963). There are numerous deposits in the Applegate group. In the Dothan, Rogue and Galice formations there are a few small prospects but they appear to be of no economic importance. Only one deposit is known from the post-Nevadan rocks.

### Tertiary Rocks

The Tertiary rocks include the Eocene Umpqua, Tyee and Spencer formations and the Eocene-Oligocene Fisher formation. These rocks have been described by Hoover (1963) for the Anlauf-Drain quadrangles. The Blackbutte mine is located in the southwest corner of the Anlauf quadrangle. Mercury mineralization is known to occur within all of these units (Brooks, 1963).

The following is a summary of Hoover's descriptions. A generalized stratigraphic section is given in figure 2 as summarized from plate 2 of Hoover (1963).

### Eocene Formations

The Umpqua formation has been divided into three members, the lower basalt, the middle tuff and the upper siltstone. The lower basalt member is a sequence of amygdaloidal or vesicular olivine basalt flows. They are overlain by or interbedded with waterlaid pyroclastics consisting of fine vitric tuff and a smaller amount of lapilli crystal tuff. Most samples contain calcite as a cement or as very thin layers approximately parallel to bedding planes. The basalt member and tuff member are overlain and in places interbedded with fine grained marine sediments including well indurated siltstone, sandy siltstone and basaltic sandstone. The thickness of the Umpqua formation exposed in the Anlauf-Drain area is about 12,000 feet.

The Tyee formation is a sequence of rhythmically bedded sandstone and siltstone which attains a maximum thickness of about 5,000 feet in the Anlauf-Drain area. It is separated from the overlying Fisher formation in the northern half of the Anlauf quadrangle by the Spencer formation. This massive arkosic sandstone consists of predominantly fine to medium grained sandstone in the

Figure 2. General Tertiary section of rocks in the Anlauf and Drain quadrangles (after Hoover, 1963).

<u>Formation and Age</u>	<u>Thickness and Lithologic Description</u>
Basalt Flows Miocene (?)	100 feet. Basalt, dark-gray glassy, locally porphyritic; contains olivine.
Fisher formation Eocene- Oligocene	5500 feet. Variegated massive or lenticular nonmarine pyroclastic rocks. Includes fine to coarse tuff, tuffaceous sandstone and siltstone, pebble to boulder conglomerate, and water-laid and mudflow breccia. Also contains interbedded andesite.
Spencer formation Eocene	150 to 500 feet. Sandstone, friable, massive, arkosic and micaceous; overlain by light-colored thin-bedded sandy siltstone and fine tuff. Contains a few lenticular beds of carbonaceous siltstone and impure coal, and a thin bed of pebble conglomerate at base.
Tyee formation Eocene	1500 to 5000 feet. Sandstone, medium-gray to greenish-gray, fine- to medium-grained, arkosic and micaceous, in graded beds generally 1-5 feet thick; upper part of each bed consists of dark-gray sandy siltstone; locally contains thin beds of intraformational conglomerate.
Umpqua formation Eocene Siltstone member	750-5000 feet. Siltstone, dark-gray, well-indurated, well-bedded, with intercalated thin beds of well-indurated fine-grained basaltic sandstone. Contains 300 foot tongue of basaltic sandstone in upper part.
Tuff member	0-200 feet. Tuff, greenish-gray, well-bedded, fine to lapilli; vitric and crystal; commonly calcareous.
Basalt member	3800+ feet. Basalt, dark-gray to greenish-black, amygdaloidal and vesicular; occurs in flows commonly 20-30 feet thick; locally brecciated.

Base not exposed

lower part and thin bedded, light colored, platy, sandy siltstone and fine tuff in the upper part. The Spencer formation is lithologically similar to the Tyee from which it probably was derived.

### The Fisher Formation

The Fisher formation, the host rocks of the Blackbutte mine, is noted for a diversity of pyroclastic and volcanic rock types. The pyroclastics, which constitute most of the formation, are made up of massive to well bedded fine to lapilli tuff, tuffaceous sandstone and siltstone, pebble to boulder conglomerate, and both water laid and mudflow breccias. The lava flows are predominantly hypersthene-augite andesite but range from basalt to dacite in composition.

Pyroclastic units. The conglomerates, which are more abundant in the lower part of the formation, have clasts whose diameters vary from one-fourth inch to 30 inches. Generally outcrops of the conglomerate are very deeply weathered with many of the pebbles being completely decomposed. In contrast, the massive water laid and mudflow breccias are reported to be relatively resistant to erosion and form bold outcrops. The breccias are more abundant in the upper part of the formation. Petrographic examination by Hoover (1963) of the breccia exposed on the northeast side of Cottage Grove reservoir north of the mine shows that it contains

lithic fragments of porphyritic andesite with phenocrysts of zoned plagioclase, mainly andesine (An 32), abundant subhedral crystals of more calcic andesine (An 42), a few crystals of clinopyroxene and magnetite, and a matrix of fine vitric tuff.

The bulk of the formation varies from tuffaceous siltstone to lapilli tuff, medium grained tuffaceous sandstone being most common. The units are massive to moderately well bedded and are various shades of green, gray, red and purple. They are composed mainly of subangular granule size fragments of andesitic and dacitic rocks and subhedral crystals of plagioclase and clinopyroxene, all in a matrix of very fine grained tuffaceous sandstone or siltstone.

Although there are no marine fossils in the Fisher formation, there are abundant fossil plants and carbonaceous material in some of the tuff units. Several locals within the mine had some carbonaceous material including a log approximately 18 inches in diameter, exposed in the 900 east portal cross-cut.

Lava flows. The lava flows, according to Hoover (1963), are mainly holocrystalline basaltic andesite, usually porphyritic, with an intersertal texture. The phenocrysts, which may make up as much as 20 percent of the rock, are augite, hypersthene and plagioclase. The plagioclase may be as calcic as labradorite (An 56) although the abundant laths in the groundmass normally are andesine (An 44-50).

About 50 percent of the rock is plagioclase, 8 percent hypersthene, 22 percent clinopyroxene, 13 percent magnetite and 7 percent partly devitrified brown glass.

A portion of Hoover's geologic map covering the mine area has been reproduced in figure 3.

Samples of the Fisher formation outside of the hydrothermal alteration zones were collected during the present study from one and one-half miles north of the mine from outcrops along the Coast Fork of the Willamette River. They represent two different flow textures and a crystal tuff. Mineralogically, they correspond with Hoover's descriptions. FF-1 has some augite phenocrysts plus smaller grains in a groundmass of small, generally aligned plagioclase grains. FF-2 has a greater variation of grain size with some larger plagioclase and augite-hypersthene phenocrysts in an irregular mass of finer plagioclase and crystallites. FF-3 was a fine grained crystal tuff with some plagioclase and pyroxene phenocrysts. Photographs of these textures are illustrated in plates 1a, 1c and 2a. Examination of the less than 2 micron fraction of these samples indicates predominantly a nearly completely expandable montmorillonite.

### Intrusive Rocks

Intrusive rocks of the Fisher formation and older Tertiary formations were described by Hoover (1963) and Wells and Waters (1935). They include dikes, sills and

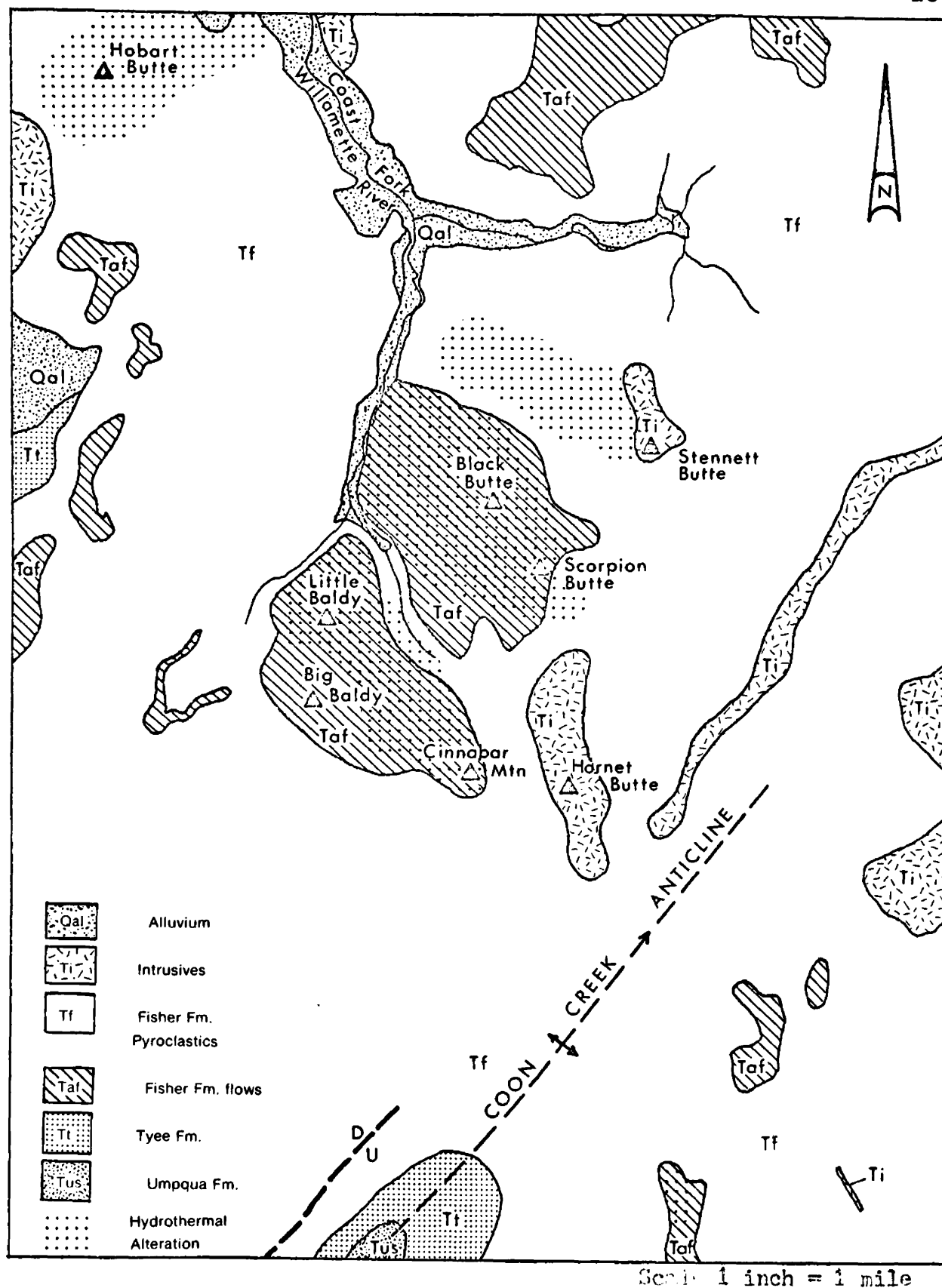


Figure 3. Geologic map of the Blackbutte mine vicinity.  
(from Hoover, 1963)



stocklike bodies of basalt, diabase and norite. Several of the oval or elliptical bodies (figure 3) were mapped by Hoover in the Black Butte vicinity and are considered to be volcanic necks. In the Fisher formation, where the largest number of intrusives were found, they are called either hypersthene-augite andesitic basalt or diabase depending on the texture and color index (Hoover, 1963).

Wells and Waters (1935) have noted a chemical similarity between some of these intrusives and an augite diorite plug in the Bohemia mining district, about 20 miles to the east. The Bohemia district rocks are possibly late Miocene in age (Buddington and Callaghan, 1936). This correlation appeared tenuous to Hoover but because of a lack of evidence, the intrusive rocks in the Fisher formation are considered to range in age from late Eocene to late Miocene.

#### Regional Hydrothermal Alteration

Stratigraphically, the Blackbutte mine is located in the upper part of the Fisher formation (Hoover, 1963). Several localities besides Black Butte show evidence of hydrothermal alteration (figure 3). In the earlier Tertiary formations, the most noted areas are the Bonanza and Elkhead mercury mines in the Umpqua formation. The most prominent area of alteration in the Fisher formation other than Black Butte is Hobart Butte located 3 miles northwest of the mine. Kaolin clay has been mined from near the top of the butte and used for refractory purposes since the 1930's.

Allen, Loofbourow and Nichols (1951) postulated a primary sedimentary source combined with a weak surficial hydrothermal alteration for the origin of the kaolin at the Hobart Butte deposit. Scorodite (hydrous ferric arsenate) has been reported (Denning, 1943) and was noted during the present study. Realgar was also noted along slickensided surfaces at the largest open pit. The close association of these hydrothermal minerals and a textural resemblance to alteration at Black Butte gives one the impression that this entire deposit, including the kaolin, is hydrothermal in origin.

Although these large areas of hydrothermal alteration have been mapped, only the areas of known mercury mineralization show significant silicification. The remaining areas consist of almost exclusively clay minerals and consequently, a more subdued topography.

## Chapter 3

### STRUCTURAL GEOLOGY

#### Regional Structure

Paleozoic and Mesozoic rocks exposed in the Klamath Mountains were deformed during the Jurassic Nevadan orogeny. Some conglomerates and sandstones, which were mildly deformed during the Cretaceous, were deposited following this event. Following this, the marine Umpqua formation of early Eocene was deposited. This unit was subjected to mild deformation, which is evidenced by local unconformities between the Umpqua and Tyee formations. During the middle Eocene, the Tyee was deposited during a period of relatively stable conditions. However, prior to the deposition of the Spencer formation in late Eocene, these rocks were deformed into a series of northeast trending folds. These folds form a part of the eastern flank of the Coast Range anticlinorium (Hoover, 1963).

Three doubly plunging anticlines of the Coast Range anticlinorium trending northeast-southwest have been mapped in the Anlauf-Drain quadrangles. They have Umpqua formation exposed in the cores and Tyee formation along the flanks. A

fourth anticline located 3 miles south of the mine also involves the Fisher formation. Southward into the Glide quadrangle, a fault parallel to the anticline turns south and cuts across the anticlinal axis and the fault then becomes the contact between the Fisher and Umpqua formations and the Coast and Cascade Ranges (Hoover, 1963).

Most faults of the Anlauf-Drain area are northwest trending normal faults with displacements downward on the northeast side (Hoover, 1963). The Black Butte fault, the major structural element in the Blackbutte mine, is essentially parallel to this trend but was omitted from Hoover's map. He was unable to see evidence of its existence except from the underground workings.

Faults can only be recognized from anomalous stratigraphic relations especially in the very heterogeneous Fisher formation. The recognition is further hindered by poor exposures and intense weathering. Consequently, the Black Butte fault is impossible to trace beyond the immediate mine vicinity and the area of its associated silicification.

#### Structure Within the Mine Workings

The following description of the Black Butte fault was compiled from observations in the accessible mine workings. The Black Butte fault strikes generally N 70° W. The dip varies from 50° to 75° to the northeast. It is essentially a fault zone up to 200 feet or more in width and is

illustrated in section A-A' (plate 8, back folder). The outcrop is marked by exposures of silicified ribs which are as much as 100 feet high. The ribs, composed of silica-carbonate rock, are located along and just above the footwall contact. The remainder of the fault zone, exposed along the north facing slope of the butte, is characterized by less silicification and softer rock which was more easily eroded.

Above the 500 level in the mine, a sharp fault or faults served as the loci for ore deposition. The 200, 300 and 400 stopes (see plate 7 in back folder for location) occur between two sharp fault planes which are 5 to 10 feet apart. West of these stopes there is a slight change in strike possibly due to intersection with a cross-fault. Above the 400 sublevel, only the upper fault plane has been exposed (section A-A'). The lower fault was not followed upward by mining since the zone of mineralization spreads out beneath the upper fault and the ore grade drops below the minable limit (plate 5d). West of this area, silicification is evident; however, to date, no economic ore bodies have been discovered in this area.

The two closely spaced faults again begin to spread apart below the 500 level. The lower fault begins to follow a steeper dip as indicated in section A-A'. The upper fault forms the back or roof of the Big Stope. Compared to the sharp upper faults, the faults on the 900 and lower levels are not as distinct and are more irregular in both strike and dip.

On the 1100 level, east end, a basalt dike roughly parallel to the Black Butte fault trend was noted. There were several well defined faults in this area which were traceable for distances of 200 to 300 feet (see figure 7). Most of these faults are generally parallel to the basalt dike; however, the dike does cut across one of the faults in the vicinity of the 34 stope. An additional discussion of structures in the 1100 east end stopes with respect to mineralization is presented in the section on ore occurrences.

The character of the faulting noted in the longer portal cross-cuts north of the fault zone has been projected from the 1100 cross-cut onto section A-A'. These faults have dips varying from 20 to 35 degrees less than the main Black Butte fault.

The attitude of the Fisher formation rocks at the Black-butte mine is not known. Anomalous lithologic changes across sharp fault planes does, however, suggest either appreciable pre-mineralization movement or that faulting occurs along bedding planes. Since the faults appear relatively continuous and there are considerable lithologic variations along their dip, the faults probably cut across bedding planes. Thus, it is suggested that the attitude of Fisher formation rocks at Black Butte dip at a smaller angle than the Black Butte fault.

## Chapter 4

### MINERALOGY

Previously reported minerals in addition to cinnabar, metacinnabar and native mercury at Blackbutte include, "carbonates and clay minerals, with variable amounts of chalcedony and quartz, and minor amounts of opal, chlorite, sericite, pyrite and marcasite" (Waters, 1945, as quoted in Brooks, 1963). The present study has noted the occurrence of cinnabar, native mercury and pyrite. Newly observed minerals include arsenopyrite, tetrahedrite, sphalerite and chalcopyrite. The non-sulfide minerals observed include quartz, kaolinite, calcite, siderite and mixed layer illite/montmorillonite. The secondary minerals produced from weathering are limonite (goethite) and gypsum. Chlorite and sericite were not found in any samples from the mine during the present study, presumably because of limited access to the upper levels of the mine.

Samples for analyses were selected from over 400 samples collected from the active operations on the 1100 level, east end and the 1200 level, plus from the older, accessible underground workings. Identification of the minerals and

and their relations was done utilizing 12 polished sections and 81 thin sections and, when possible, the identity was substantiated by x-ray diffraction. The clay minerals were identified in 56 samples which show various degrees of alteration. The author used the x-ray diffraction identification method of Kinter and Diamond (1956) for oriented clay samples. Initially the samples were broken and the clay minerals were removed using an ultrasonic disaggregator. The clay was mounted on a porcelain plate and was run on x-ray diffraction from  $32^{\circ}$  to  $2^{\circ}$  in order to scan for all possible clay mineral diffraction peaks.

#### Sulfides and Mercury Minerals

Cinnabar -  $\text{HgS}$ . Cinnabar is the most common mercury mineral at Blackbutte. It occurs as disseminated grains and in veinlets up to two or three inches wide. The smaller disseminated grains and coatings along fractures are bright red in color. The larger disseminated grains and veinlets generally have a grayish to lavender red color. When scratched, the typical vermillion red streak is easily produced.

Thin coatings and small disseminated grains of cinnabar lining fractures and cavities produced by faulting and brecciation, and widely disseminated cinnabar grains were common in the 1100 level, east end ore bodies. It also fills apparent fractures in the earlier sulfides and in



calcite and sometimes replaces them, apparently migrating away in one direction from the fracture (plate 6c). Small veinlets were most abundant on the upper levels of the mine.

Tetrahedrite -  $(\text{Cu,Hg,Zn,Fe})_{12}(\text{Sb,As})_4\text{S}_{13}$ . Tetrahedrite was identified in polished section and from small tetrahedral crystals which were identified by x-ray diffraction. Blebs of the mineral in massive cinnabar were found up to 1 mm in diameter and, to the naked eye, were clearly visible on polished surfaces. Small cinnabar veinlets cut the tetrahedrite indicating the cinnabar was later. A rim of chalcopryrite surrounds tetrahedrite (plate 6a) in a sample from the 1200 level. This sample is the only one showing the close relationship of chalcopryrite and tetrahedrite. The two minerals were not in contact in polished sections from the 900 and 1100 levels. Tetrahedrite was also noted between autoclasts of pyrite-arsenopyrite veinlets.

Tetrahedrite was not found in samples above the 900 level, possibly because of limited access for sampling on these levels; therefore, conclusive evidence of its absence is lacking.

Schwazite (mercurian tetrahedrite) is commonly associated with cinnabar deposits and is the only primary mercury mineral in prospects of the Steens and Pueblo Mountains of southeastern Oregon (Williams and Compton, 1953). X-ray diffraction patterns of the tetrahedrite from Blackbutte most closely fit zincian tetrahedrite (Smith, 1960), in the absence of

data for schwazite. The color description in Uytendogaardt (1971) for schwazite matched those in polished section. The remaining optical properties for tetrahedrite and schwazite are too similar to allow differentiation. Consequently, from the best available data, the mineral is tentatively identified as mercurian tetrahedrite or schwazite.

Metacinnabar - HgS. Small amounts of metacinnabar were reported by Waters (1945) from the Big Stope; however, metacinnabar was not found in any samples collected during the present study.

Native Mercury - Hg. Waters (1945) reported the presence of small amounts of native mercury from the Big Stope. A small amount was noted along a fracture during the recent operations above the 300 level. There were no reported sightings of the mineral by miners on the 1100 and 1200 levels.

Pyrite -  $\text{FeS}_2$ . The earliest hypogene sulfide deposited in the mine was pyrite. Small disseminated grains including what may be some pre-alteration pyrite are common in most samples. Massive pyrite veinlets with associated arsenopyrite are found along fault planes and in gouge or brecciated zones between closely spaced faults (plates 6b, 6c). In polished section these veinlets show brecciation, and quartz-kaolinite, tetrahedrite and goethite are found between the clasts. Pyrite veinlets are often the loci for deposition of later sulfides.

Arsenopyrite -  $\text{FeAsS}$ . Arsenopyrite was noted as small grains dispersed with pyrite of the same habit. There are

no apparent time relations in polished section, suggesting the minerals may have been deposited contemporaneously. The mineral was not found among individual disseminated grains. A grain of twinned arsenopyrite is illustrated in plate 6b.

Marcasite -  $\text{FeS}_2$ . Marcasite together with pyrite (both verified by x-ray) was found in gouge along a fault on the 1100 level, east end. Waters (1945) reports its presence in variable amounts.

Sphalerite -  $\text{ZnS}$ . A mineral tentatively identified as sphalerite occurs as small, dark gray blebs together with the cinnabar. Microveinlets of cinnabar cut across these small grains (plate 5a) indicating they were the earlier of the two sulfides. Positive identification as sphalerite is difficult because the small grains are easily masked by the internal reflections and anisotropy of cinnabar. Sphalerite and cinnabar are commonly associated in cinnabar deposits. Relative intensities of x-ray fluorescence peaks indicate much more zinc than copper in sulfide samples (direct comparison of fluorescence peaks to obtain relative amounts is valid for two elements with very similar atomic weights). Tetrahedrite is essentially a copper-antimony sulfide. Therefore, though some zinc may occur in tetrahedrite, the amount of zinc in samples indicates another zinc phase. The gray blebs of sphalerite are present with massive cinnabar in quantities up to 2 or 3 percent of the total sulfides in some samples (plate 5a).

Chalcopyrite -  $\text{CuFeS}_2$ . Small blebs of chalcopyrite (plate 5a) were noted in polished sections from the 900, 1100 and 1200 levels. Small veinlets of cinnabar cut the chalcopyrite indicating the cinnabar was the later mineral. The dark gray material lining a cavity in the 32 stope of the 1100 level was identified by x-ray as chalcopyrite with tetrahedrite.

#### Non-sulfide Gangue Minerals

The two most abundant minerals produced by hydrothermal alteration are quartz and kaolinite. Calcite and siderite are less abundant and have also been subjected to leaching by groundwaters. A small amount of hydrothermal, mixed layer, illite/montmorillonite was the only other clay mineral present.

Quartz. Quartz is very fine grained (plate 3c); consequently, it was difficult to obtain an interference figure in thin section. X-ray diffraction patterns indicate it is alpha-quartz (Smith, 1960). It varies from very fine in less intensely altered areas to a noticeably coarser grain size in areas of silicification. Hand specimens of quartz-kaolinite are noted for their physically soft, "punky" nature due to their lesser degree of induration. Where silicification is complete, the rock is harder and more compact and lacks a "gritty" touch. Silicification is defined (Gary, McAfee and Wolf, 1972) as "the introduction

of, or replacement by, silica generally resulting in the formation of fine-grained quartz, chalcedony or opal, which may both fill pores and replace existing minerals." At Blackbutte, fine grained quartz was introduced with the increasing alteration intensity. Increased whole rock quartz amounts were determined by comparison of x-ray peak intensities of the 3.34 Å peak of quartz with the 7.15 Å peak of kaolinite in rocks from sites of various degrees of alteration (for results, see Hydrothermal Alteration, Zoning).

The silicified ribs, exposed at the top of the butte, are predominantly fine grained quartz. The ribs were later brecciated and cemented by siderite (plate 4d).

Kaolinite. Kaolinite occurs as small veinlets and as soft, white grains formed as a result of alteration of plagioclase phenocrysts in porphyritic flows and crystal tuffs (plates 3e, 3f). In thin section the soft relict phenocrysts consist of a mass of extremely fine grains which cannot be readily differentiated from fine grained quartz. Hand picking of the soft white relict phenocrysts for x-ray diffraction analysis indicates it is kaolinite (plate 3c). In most cases, it was impossible to differentiate between quartz and kaolinite in thin section; consequently, it is referred to as "quartz-Kaolinite".

Dickite, a polymorph of kaolinite, has been identified as the hydrothermal, high alumina, clay mineral at the Red Devil mercury mine in Alaska (MacKevett and Berg, 1963).

Unoriented samples of clay minerals from the Blackbutte mine indicated it is kaolinite and not dickite. The kaolinite is partially b-axis disordered as shown by comparison of x-ray diffraction patterns with diagramatic patterns in Brown (1961, p. 67).

Illite/Montmorillonite. Three specimens from the 300 level, east portal cross-cut (see plate 7 in back folder for location), approximately 300 feet east of any mined area, contain in addition to kaolinite, mixed layer illite/montmorillonite. The samples were obtained near the portal and at the face of the cross-cut. The mixed layer illite/montmorillonite was compared with calculated x-ray diffraction patterns (Reynolds and Hower, 1970) to estimate percent expandability. All three samples consist of about 30 percent expandable, regularly interstratified, mixed layer illite/montmorillonite.

There are no known occurrences of a regularly interstratified, mixed layer illite/montmorillonite with expandability as low as 30 percent which has been produced in a weathering environment. Consequently, it probably is a result of hydrothermal alteration. Furthermore, analysis of clay samples from the Fisher formation outside of the hydrothermal alteration zone are nearly completely expandable. Thus, the three samples of 30 percent mixed layer expandable clay appear to be restricted to a portion of the hydrothermal alteration.

Calcite. Calcite is common but not universal in rocks where silicification is less intense. It varies from disseminated grains to massive veins. A 30 foot wide vein of calcite on the Dennis Creek level was mined for chicken grit (Wells and Waters, 1934). Small veinlets of calcite were associated with the basalt dike on the 1100 level. In the tuffs, calcite is found as disseminated grains usually in the interstitial areas of groundmass between altered plagioclase phenocrysts (plate 1d). Plate 3a shows that calcite has become the dominant carbonate, rather than siderite, along a discolored or bleached band.

The abundance of calcite decreases toward the upper levels of the mine. However, abundant limonite and vugs suggest weathering and probable acid rich groundwaters which could have leached calcite if it had been present. Large cavities such as the one between the 900 west and Dennis Creek levels, are produced from the solution of calcite (Wells and Waters, 1934). Consequently, the lesser amount of calcite in or adjacent to highly silicified rocks on the upper levels is inconclusive of its pre-weathering extent. Small irregular areas of silicification in the 1100 level, 32 stope had abundant calcite adjacent to the densely silicified rocks.

Siderite. Siderite occurs in many different forms in the Blackbutte mine. Its identity was substantiated by x-ray in all cases. At the top of the butte, it is abundant

as a dark brown cementing material for silicified and then brecciated rocks (plate 4d). Spherulites of the mineral, which are numerous on the 1100 level, are greenish gray to golden in color and can occur as either fine grained masses in a weakly altered host rock or recrystallized masses in a silicified host rock (plates 1e, 1f). Veinlets and irregular masses are also associated with the spherulites in some of the silicified units.

A pod of fine grained, reddish brown, material from the 32 stope, 1100 level, was identified as siderite by x-ray. Thin section examinations indicate partial alteration of the siderite, especially along fractures. Siderite is also found with some calcite inside reddish brown concentric bands formed in clasts of brecciated andesite. The bands apparently are hematite stained quartz formed by oxidation of the siderite (plate 3b). Thin sections of lesser altered rocks indicate they often contain anhedral to euhedral siderite easily discerned by its high relief and red-brown to black color.

Generally siderite can be found in all areas of the mine. The amount and type, however, is quite variable.

Limonite. Limonite has been defined by Blanchard (1968, p. 7) as, "the reddish, yellowish, brownish or brownish-black deposits formed by decomposing iron-yielding minerals or substances of nature, regardless of origin."



Types of limonite at Blackbutte include massive goethite, limonitic jasper, limonite halos (adjacent to massive pyrite-arsenopyrite veinlets), fluffy limonite and a general disseminated limonite stain.

Massive goethite is found as grains possibly replacing quartz and as veinlets adjacent to massive pyrite-arsenopyrite veins (plate 6c). It also has been noted replacing cinnabar from samples near the top of the butte (plate 5b). Limonitic jasper is abundant on the upper levels of the mine as thick seams probably formed from the alteration of massive to semi-massive pyrite-arsenopyrite (Blanchard, 1968). Limonitic halos around massive pyrite-arsenopyrite veinlets were noted in polished section (plate 6d). Polishing of this sample revealed the presence of fresh iron sulfides within what appeared to be areas of predominantly limonite.

Fluffy limonite was found in a large cavity on the 1200 level. The cavity was probably produced when calcite was removed by groundwater solutions. Blanchard (1968, p. 66) reports, "when an adequate supply of calcium or magnesium carbonate or bicarbonate is available to react rapidly with the ferric sulfate, the precipitated limonite particles tend to fluff up during their formation." A general yellow-brown stain (plate 4b) occurs in the bleached quartz-kaolinite rocks of the mine except on the 900 east and 1100 east levels where the stain was minor.

Gypsum. Gypsum crystals were noted in some of the mine drifts where groundwaters percolated into the mine. They can be formed from the apparent calcium sulfate rich waters within a few days after the area is opened by mining. Gypsum crystals were also found with the fluffy limonite.

## Chapter 5

### HYDROTHERMAL ALTERATION

The Blackbutte mine had been described as, "profoundly altered ---- andesitic lavas and pyroclastics" (Waters, 1945, as quoted in Brooks, 1963). The majority of the published work on the mine (Wells and Waters, 1934; Waters, 1943, 1945) has concentrated on the silicification along the Black Butte fault. Additional silicification was noted in the tuffs of the Smoky stope (Waters, 1945). The remaining rocks were described as bleached and soft rock composed of largely carbonates and clay minerals (Waters, 1945). The present study has, with information from the most recent mining, noted a gradational trend from less to more intensely altered rocks when moving toward the ore zones.

An attempt was made to identify possible deuteric minerals at Blackbutte. Sample FF-2 from the Fisher formation contains large grains of calcite very different from the interstitial calcite of less altered mine rocks. This calcite may or may not be deuteric. Calcite of similar habit was not found in the mine. The remaining mineralogy at Blackbutte was the same throughout all degrees of

alteration and definite confirmation as to a deuteric origin was impossible.

Weathering has produced a limonite stain throughout most of the mine in rocks of the more intensely altered zones. If weathering had produced its own clay mineral suite, it would be expected to differ from the clay suite of the unweathered areas. This is not the case at Black-butte as the clay is all kaolinite. The clay mineral from non-hydrothermally altered rocks is nearly completely expandable montmorillonite. Consequently, weathering probably has affected only the carbonate and iron minerals at the mine.

### Textures

Three basic textures have been described in rocks from outside the hydrothermal alteration. They have been represented in plates 1a (andesite, subparallel plagioclase laths), 1c (andesite, porphyritic) and 2a (crystal tuff). Relict textures in rocks inside the mine, when not destroyed by intense alteration, are usually similar to one of these types. Examples of each are represented in plates 1b (similar to 1a), 1d (similar to 1a) and 2b and 2c (similar to 2a). Megascopic textures of the conglomerates and breccias are often masked by the alteration. However, in many cases, when these rocks were slabbed the outlines of individual clasts became apparent.

The alteration textures consist of very fine interwoven anhedral grains of quartz-kaolinite. Grains of calcite and siderite are usually larger than the quartz-kaolinite grains.

### Zoning

Initially an attempt was made to see if a zonation was reflected in the clay mineral distribution at Blackbutte. This is not the case because almost all samples contained only kaolinite. Three samples of regularly interstratified, mixed layer illite/montmorillonite (see Mineralogy, Illite/Montmorillonite) suggests an outer zone of less intense leaching, but the small number of samples precludes any definite conclusions.

Three zones, an outer, intermediate and an inner zone are proposed which are based upon the degree of alteration and bleaching as noted in mine exposures. Several textural and mineralogical characteristics have been noted in the proposed zones; however, these characteristics are not found in all areas of an individual zone. The distinctions between zones are based upon horizontal variations largely on the 900, 1100 and 1200 levels plus available vertical observations. The initial "type" rock of each zone was based upon day to day underground observations. The silicified rock of the inner zone is very hard and brittle and was easily shattered by the mine blasting. The rock of the outer zone is fresher appearing, usually a medium to dark brown or gray. Rock of

the intermediate zone is bleached to a white, light gray or light pink color and is soft and "punky" in comparison to the hard, brittle inner zone rocks.

Quartz increases relative to kaolinite between the intermediate and inner zones as would be expected with increasing silicification. However, the irregular nature of the alteration between the outer and intermediate zones has resulted in an irregular distribution of the quartz-kaolinite. This conclusion is based upon examination of samples selected from each of the three zones. The whole rock portions of each sample were run on x-ray diffraction from  $32^\circ$  to  $10^\circ$ , which covers the  $3.34 \text{ \AA}$  peak of quartz and the  $7.15 \text{ \AA}$  peak of kaolinite (see Patterns in Appendix). The ratio of these peak intensities was used to determine the relative changes of the minerals in each of the zones. A portion of each sample (80-100 grams) was crushed to 32 mesh and split to obtain a sample for x-ray analysis. The smaller sample was hand pulverized for 15 to 20 minutes and was mounted on a glass slide using a thin layer of petroleum jelly for adhesive. The results of the intensity ratios are presented in the following table.

<u>Inner Zone</u>		<u>Intermediate Zone</u>		<u>Outer Zone</u>	
Sample	Qtz/Kaol	Sample	Qtz/Kaol	Sample	Qtz/Kaol
1232	6.91	1130	4.25	1236	3.61
993	5.53	1242	3.52	1139	2.30
1222	5.50	1270	3.50	1155	1.54
1237	4.71	1245	3.33		

Another sample (#1172 from the intermediate zone) was selected because it contained both bleached and unbleached rock similar to the example in plate 6e. The quartz to kaolinite x-ray intensity ratios were

#1172 (bleached)	=	3.00
#1172 (unbleached)	=	1.83

The average quartz to kaolinite ratio from the inner zone is 5.66 with a standard deviation of 0.84. The average for the intermediate zone is 3.65 with a standard deviation of 0.17. An average with a standard deviation was not calculated for the outer zone because of the very erratic results. The highly variable ratios may have been due to deuteric alteration, or perhaps they are a result of the incomplete alteration of the primary minerals by the hydrothermal solutions.

The results suggest that quartz is increasing (silicification) with increasing degree of alteration, and from thin section examination of inner zone rocks, quartz has replaced the kaolinite and destroyed the outlines of the phenocrysts. The increase in quartz was also noted by Wells and Waters (1934) who state, "two different alteration products, distinguished by their relative amounts of silica may be recognized; the silica carbonate veins and associated silicified rock ---- and a softer material containing sericite and abundant carbonates, especially calcite, with minor

amounts of silica." The two rock types described by Wells and Waters apparently correspond respectively to the inner and intermediate zones. Sericite was not found during the present study and presumably it is found only on the upper levels. The distribution and habit of the minerals other than the quartz-kaolinite is irregular, and consequently, it is possible to discuss them in a descriptive sense only. A description of the typical rock in the individual zones is presented in the following section.

Outer zone. The outer zone was exposed in the portal crosscuts on the 900, 1100 and 1200 levels. Thin sections reveal that the primary minerals have been partially too completely destroyed by the hydrothermal solutions. The bleaching, which is the destruction of the iron minerals and removal of the iron (plates 3a, 3b), is minor; however, partial bleaching along small fractures with centers of unbleached rock is not uncommon (plate 4c). The identifiable iron minerals are siderite and magnetite-ilmenite. The relationship of pyrite to the bleaching is unknown since its identification as pre- or post-alteration was not readily discernible.

Relict textures of the outer zone are well preserved (plates 1b, 1d). The plagioclase laths have been partially to completely altered in most cases to quartz-kaolinite and in some cases to calcite. Examples of partial replacement along twin boundaries and along plagioclase zoning boundaries



are represented in plates 3e and 3f. X-ray examination of the larger relict phenocrysts in more intensely altered rocks indicates they are predominantly kaolinite with some quartz. The relict phenocrysts are petrographically the same in samples of all degrees of alteration.

Interstitial material between plagioclase laths consists of fine grained quartz-kaolinite, calcite, siderite and opaques. Small calcite grains are very abundant; siderite is quite variable. Larger grains of siderite are common as well as smaller interstitial grains and fine grained spherulites. The larger grains of siderite are commonly dark brown to black in thin section, and they are not discernable in hand specimen. Opaques including magnetite (up to 13 percent reported in the Fisher formation) and pyrite, may be of pre-alteration origin or produced from alteration of ferro-magnesian minerals (plate 5c).

Intermediate zone. The soft "punky" rocks of the intermediate zone are characterized by nearly complete bleaching or discoloration of the original host rock. Small pods or remnants of unbleached rock with gradational boundaries are the only evidence of pre-alteration color (plate 6e). Thin sections reveal the predominantly quartz groundmass has increased in grain size from the unbleached outer zone. The later stage calcite is common as disseminated grains and small veinlets. Siderite is leached as noted in

the 32 stope, 1100 level, where some pods of siderite have not been completely leached. Generally, siderite is removed and calcite is added to rocks of the intermediate zone.

Opaques, with the exception of pyrite, are also leached from the intermediate zone. Disseminated grains and small veinlets of pyrite are common.

Textures of the host rocks are usually well preserved but the original minerals have been completely replaced or removed in the intermediate zone.

Inner zone. The inner zone is characterized by complete to almost complete silicification of the wall rock. The kaolinite decreases in favor of quartz and the grain size of the quartz again increases over that of the intermediate zone. Some relict textures were discernable but most have been destroyed.

Siderite spherulites (1 to 3 mm in diameter) and small grains and veinlets of siderite are enclosed by fine grained quartz (plate 1f) and are abundant in the silicified rocks of the 1100 level, east end. Siderite cementing of silicified and then brecciated rock is most abundant on the upper levels of the mine in the silicified ribs.

Calcite veins and some calcite replacement of silicified rocks (plate 3d) are not uncommon. Disseminated grains of calcite were not found in completely silicified rocks except when calcite apparently replaced quartz within inches of a calcite vein.

The carbonates were deposited after the highly silicified rocks were brecciated, presumably when the solutions had moderate to high cation to hydrogen ion ratios (see Ore Occurrences, Wall Rock Alteration).

In summary, the intensity of hydrothermal alteration and bleaching in each of the proposed zones is reflected by several alteration mineralogy variations. Initial variations of the outer zone include alteration of phenocrysts and groundmass to quartz-kaolinite and formation of interstitial calcite, siderite, pyrite and magnetite-ilmenite. In the intermediate zone, alteration to quartz-kaolinite is complete. Iron minerals including siderite are removed (reflected by the bleaching) and later stage calcite is added. In the inner zone, silicification is predominant with quartz replacing the kaolinite. Calcite occurs in veins and siderite occurs as a breccia cement and in small veins and spherulites. An outline of these variations is presented in figure 4.

The bleached and more intensely altered rocks of the intermediate and inner zones in most cases were tuffs, tuff breccias and conglomerates. The 32 stope on the 1100 level was in brecciated andesite flows and the ore bodies of the R, 33 and 34 stopes were in tuff and tuff breccia.

Examples of the three zones of alteration can be seen on the 1200 level (figure 5). The portal begins in the


	<u>OUTER ZONE</u>	<u>INTERMEDIATE ZONE</u>	<u>INNER ZONE</u>
Alteration	partial to complete	intense and complete	intense and complete
Bleaching	minor	nearly complete, small unbleached pods	complete
Relict Textures	well preserved, some remnant minerals	well preserved	most, completely destroyed
Quartz	increasing grain size and abundance 		
Kaolinite	as white pocks (altered feldspar) variable abundance	as white pocks, abundant	decreasing abundance
Calcite	disseminated grains	disseminated grains and veinlets, variable abundance	large veins only, variable abundance
Siderite	small disseminated grains	partially to completely leached	breccia cement and spherulites, variable abundance
Cinnabar	none present	sparse and varied disseminated mineralization	mineralization in brecciated, silicified rocks

Figure 4. Representative diagram briefly outlining the characteristics in the three zones of hydrothermal alteration at the Blackbutte mine.

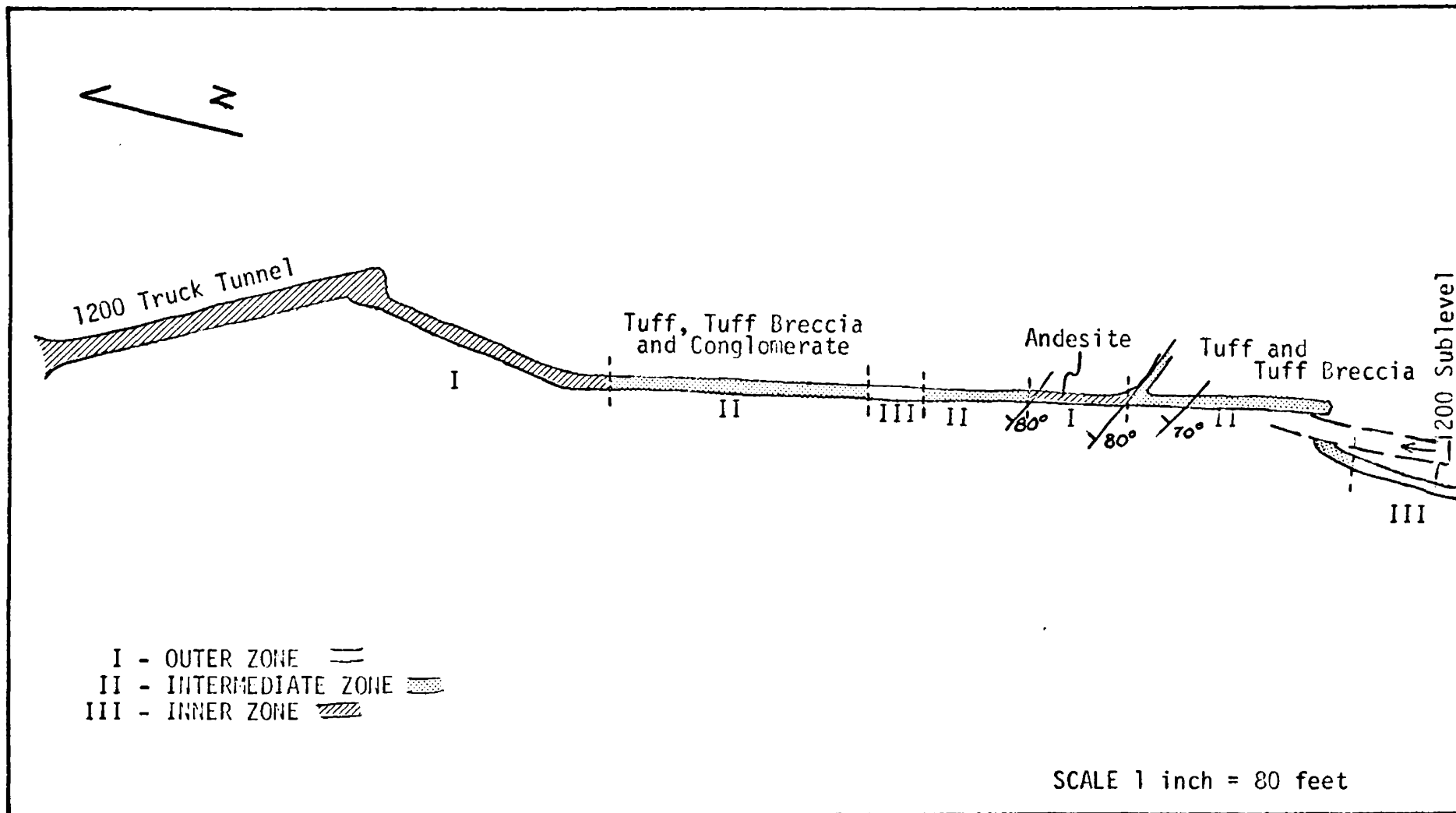


Figure 5. 1200 portal crosscut showing the hydrothermal alteration zones. The boundaries are approximate.

outer zone. Appreciable bleaching begins about 450 feet from the portal which then is in the intermediate zone. The intensity increases with minor silicification at about 640 feet. This is cut off by a fault beyond which is a dense andesite dike or flow very fresh in appearance. Thin section study indicates outer zone alteration. The less intense alteration may be due to the dense nature of the andesite, or it may be deuteric alteration of the same nature as the hydrothermal alteration.

At the junction (figure 5) where the andesite ends, the drifting begins in bleached tuffs of the intermediate zone. The cross-cut broke into an older 1200 sublevel which showed abundant silicification and is characteristic of the inner zone.

### Paragenesis

Paragenesis of ore and gangue minerals at the Black-butte mine is illustrated in figure 6. The minerals included are quartz, kaolinite, calcite, siderite, pyrite, arsenopyrite, sphalerite, chalcopyrite, tetrahedrite and cinnabar. A discussion of each of these minerals and their relations has been presented in the section on mineralogy. Additional relations with respect to the three alteration zones have also been discussed in the section on zoning.

Quartz and kaolinite are the earliest hydrothermal minerals preserved in the mine indicated by deposition of all

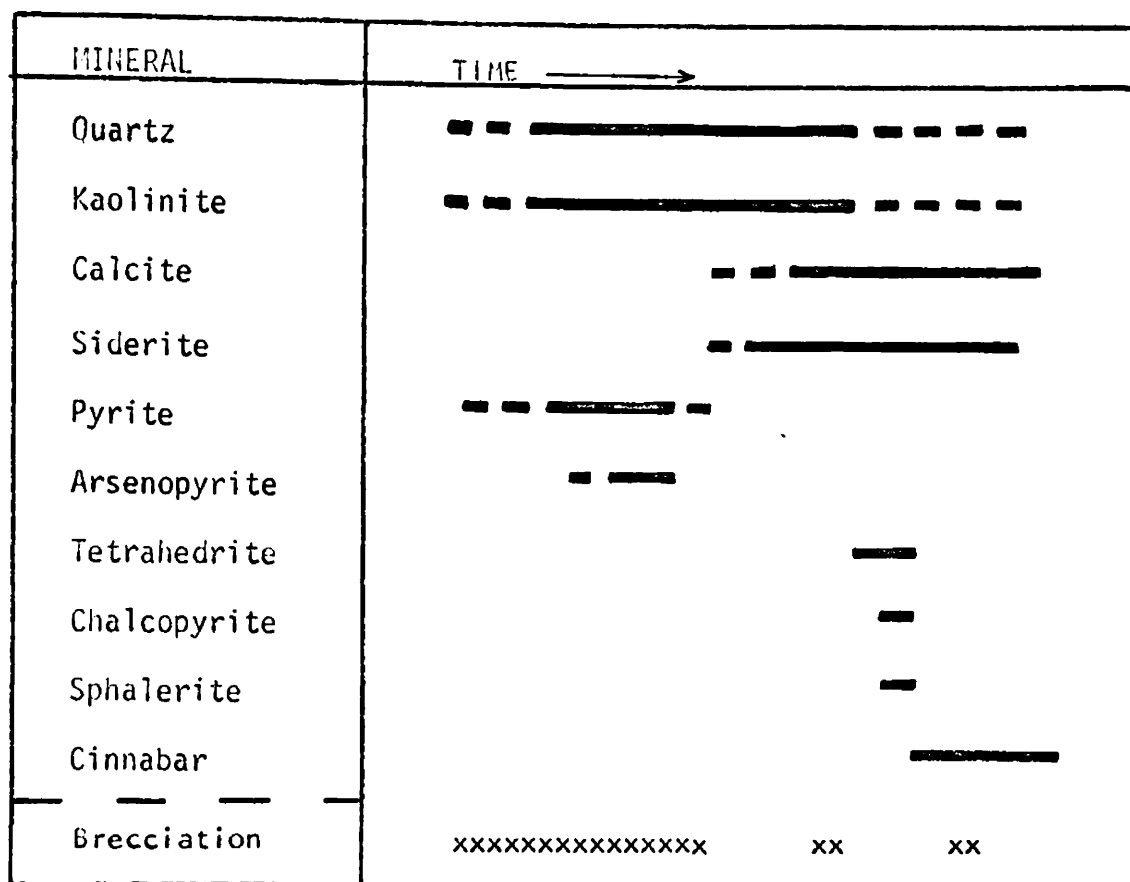


Figure 6. Paragenesis of the hydrothermal minerals for all zones at the Blackbutte mine. Dashed lines indicate questionable relationships.

other minerals between clasts of brecciated quartz-kaolinite rocks. They appear to have formed until the very latest stages of mineralization with the major amount produced during the early alteration stages. Siderite in the outer alteration zone was deposited earlier than some of the quartz-kaolinite. This is suggested by its removal (reflected by cases of incomplete removal, plate 3a) during the bleaching, which occurred predominantly in the intermediate zone. Siderite in the inner alteration zone was common between

brecciated clasts of quartz-kaolinite (plate 4d). Calcite of the outer zone probably formed at the same time as the associated siderite both of which could be deuteric rather than epigenetic. The vein calcite of the intermediate and inner zones was definitely later, with some forming later than the cinnabar.

Pyrite is the earliest sulfide preserved at Blackbutte. Pyrite-arsenopyrite veinlets were deposited in brecciated, silicified rocks and these same iron minerals have been brecciated by later tectonic activity. Arsenopyrite was found mixed with pyrite in veinlets and blebs of iron sulfides (plates 6b, 6c), but it was not found with the finely disseminated pyrite. Fine pyrite does occur in densely silicified rocks while the pyrite-arsenopyrite is found only in the brecciated, silicified rocks. This suggests some pyrite was deposited alone before combined pyrite-arsenopyrite was formed. Available textural evidence indicates the majority of the tectonic movements and brecciation occurred before deposition of the carbonates.

The next sulfide deposited was tetrahedrite which in one sample appears to have been deposited earlier than chalcopyrite (plate 6a); however, tetrahedrite, chalcopyrite and sphalerite in the other polished sections did not exhibit any time relation textures similar to the example. Consequently, they are considered to have been deposited



essentially contemporaneously, with tetrahedrite perhaps starting earlier. Cinnabar veinlets cut all of the above sulfides (plate 5a) and calcite. There are calcite crystals on top of cinnabar in a few places indicating overlapping deposition at the last stage of calcite deposition.

## Chapter 6

### ORE OCCURRENCES

Ross (1942) reported that 95 percent of all U.S. mercury production has come from cinnabar. Pure cinnabar contains 86.2 percent Hg by weight compared to 10 to 24 percent Hg in mercurian tetrahedrite (Learned, 1962). The tetrahedrite was not reported in the earlier mine reports; however, since the mineral is minor in quantity and the amount of mercury in it is also small, it apparently is inconsequential in total mercury production at Blackbutte.

The Blackbutte mine consists of 12 adits and 11 levels over a vertical distance of 1300 feet (see plate 7 in pocket). The principal ore shoot includes the Big stope and the 200, 300, 400 and 500 east stopes which were mined over a vertical distance of 850 feet (Brooks, 1963). The cinnabar from this area and also the 200, 400 and 500 west stopes occurred in small veinlets in brecciated, silicified rocks. Ore disseminated in altered andesite tuffs was developed in the later years of operation on the 900 and 1100 east levels and the 1100 west and Dennis Creek levels. The following is a description of the ore bodies on the 1100 level, east

end, examined during the recent mining activity and a summary of the major ore shoots described by Waters in 1945.

#### 1100 East End Orebodies

The orebodies on the 1100 level, east end, were in andesite, andesite tuff and tuff breccia. The 32 stope (figure 7) is in brecciated andesite (plate 4a) which is completely bleached to a gray or white color except for concentric bands of red-brown stained quartz-kaolinite. Siderite and calcite are found inside the bands, but outside of the bands the carbonates appear to have been removed by the hydrothermal solutions. A reddish brown pocket from the same stope was identified as siderite and hematite. Thin section examination showed the hematite had formed along fractures in the siderite. The small amount of very finely dispersed material in the red-brown concentric bands could not be separated and identified by x-ray diffraction; however, in thin section, it appeared the same as the reddish brown hematite from the pocket. An additional discussion of the bands and their possible bearing on solution composition is presented in the section on mineralizing solutions, since the bands are the loci for occasional heavier concentrations of cinnabar. Cinnabar, tetrahedrite and chalcopyrite were also found in the interstitial gouge and as coatings in some open cavities of the 32 stope.

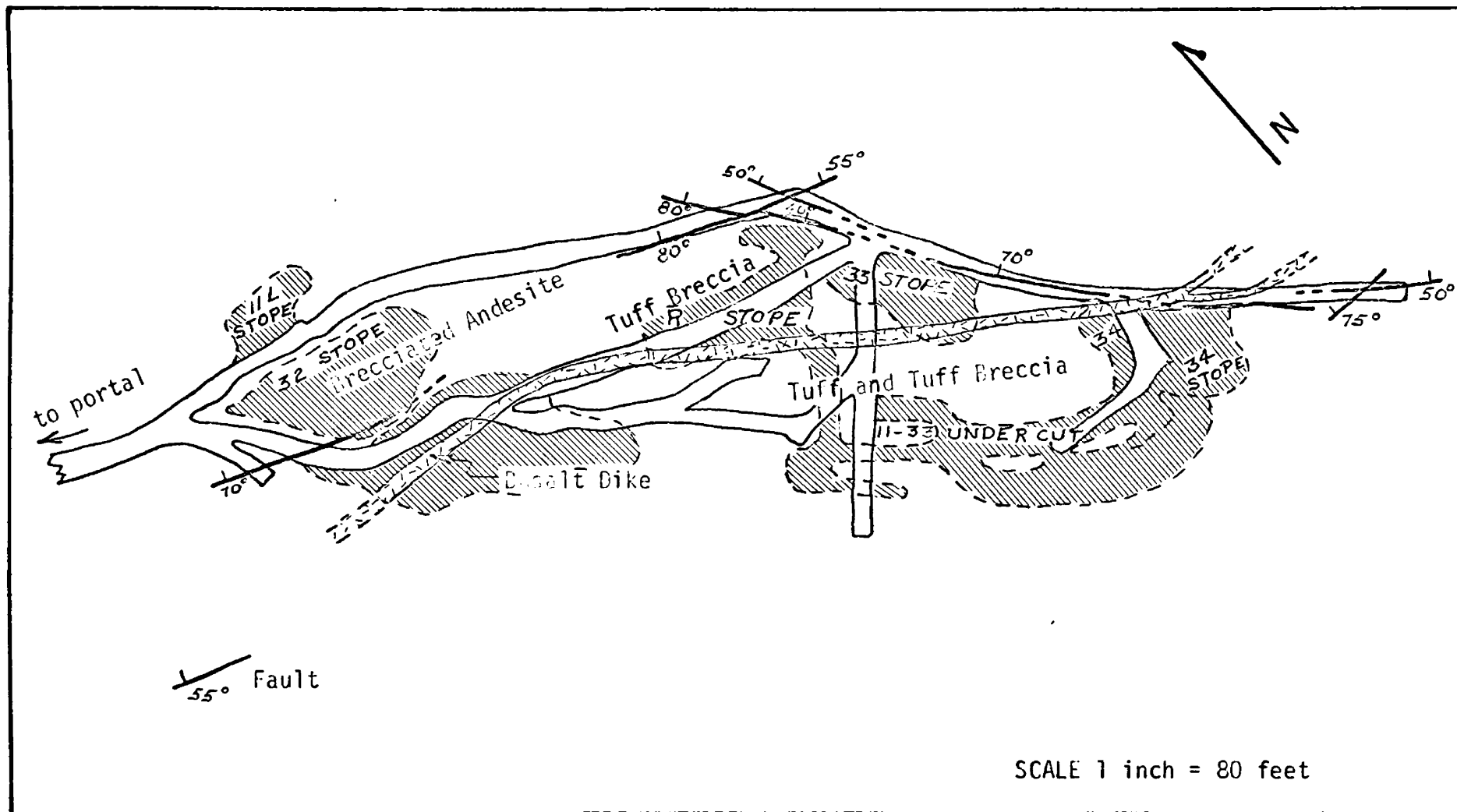


Figure 7. 1100 level, east end. Stope locations and geologic map.

The R stope (figure 7) was in tuff breccia and contained the highest grade ore obtained from this part of the mine. The cinnabar, present as fine grains disseminated through the breccia, often assayed between 3.5 and 4.5 pounds of mercury per ton. Carbonates were minor in these breccias. Tuff with lesser amounts of tuff breccia was the predominant host rock of the 33 and 34 stopes (figure 7). Silification is minor in the east end stopes with only irregular masses noted in the vicinity of the 32 stope. Extensive tectonic brecciation was noted only in the 32 stope.

A basalt dike (figure 7) was noted in the east end area with mineralization occurring along both sides of it. The dike has been altered and also contains some calcite veinlets. It does not show any bleaching; however, thin section studies indicate partial to complete alteration of the feldspars to quartz-kaolinite. The alteration is similar to that of the outer zone. Generally the dike appears to be parallel to the Black Butte fault trend and is also parallel to some faults in the immediate area. However, it does cut across the fault in the vicinity of the 34 stope. A basalt dike similar to this one, perhaps an extension of it, was noted where mining began in 1956 on the 1100 level.

### Previously Described Ore Shoots

Waters (1945, as quoted in Brooks, 1963) described the ore shoots including the Big stope, the Smoky stope and mineralization on the Dennis Creek level all of which were partly to wholly inaccessible during the present study. A brief summary of these ore shoots follows.

Cinnabar from the ore shoot along the Black Butte fault, including the Big stope and the eastern stopes above the 600 level, occurs as specks and short discontinuous veinlets adjacent to brecciated and altered rocks. The amount of mineralization is highly variable but, generally it is richest in more thoroughly silicified and then brecciated rocks. Some silicified rock, however, is nearly barren. Minalbe ore was also found in the clayey, carbonatized but unsilicified rocks adjacent to the fault.

Waters (1945) notes that the Smoky stope of the 900 level, east end, and stopes of the 1100 level, west end, are in bedded tuffs. In the Smoky stope, the best ore was found directly beneath a silicified purple-brown tuff in a highly altered, light colored tuff. The light colored tuff is composed largely of carbonates and clay but is more silicified toward the west. Waters (1945) notes that cinnabar decreases in quantity as silicification increases.

Mineralization on the Dennis Creek level reportedly is along steeply dipping fractures in a thick flow of

porphyritic andesite (Waters, 1945). This is very low grade ore.

In summary, cinnabar at the Blackbutte mine occurs predominantly in small disseminated grains (1 mm or less) in the 1100 level, east end ore bodies, which is similar to both the Smoky stope and 1100 west end stopes. The cinnabar left in pillars and other places on the upper levels was predominantly in small veinlets up to 3 inches wide and larger grains up to 3 or 4 mm in diameter. The deposition of cinnabar occurred in favorable open spaces; consequently, the finer disseminated grains are found predominantly in weakly silicified tuffs, and the veinlets are found in brecciated, silicified rocks. Massive, slightly brecciated, silicified rocks contain at most only small amounts of cinnabar. In this respect Blackbutte differs from the opalite type deposits, such as the Ivanhoe district of Nevada and the Quartz Mountain district of south central Oregon, where cinnabar is intimately associated with the silicification. Blackbutte is similar to the volcanic type of Bailey and Phoenix (1944). This includes the Cordero mine below the covering opalite blanket and the Castle Peak mine in Nevada.

### The Hg Bearing Solutions

The quantity and/or intensity of the hydrothermal solutions at Blackbutte was apparently greater in the Black Butte fault zone. The irregularity or discontinuity of faults on the lower levels resulted in a more irregular distribution of orebodies, while the sharp upper faults served as a more continuous plumbing system, localizing higher grade orebodies of more limited extent.

The temperatures of the mineralizing solutions at Blackbutte are unknown; however, they presumably did not exceed 350°C. This temperature is the upper stability limit for kaolinite (Meyer and Hemley, 1967). Dickson (1964) suggested temperatures in the range of 100°C to 230°C for most cinnabar deposits.

Depth of emplacement is unknown; however, mineralization is known on the Dennis Creek level, 1300 feet below the top of the butte. This is not the base of mineralization, so a conservative estimate of not less than 2000 feet for the deepest mineralization appears reasonable. Minimum hydrostatic pressures for 2000 feet of burial is approximately 60 bars (Dickson, 1964).

The period of calcite and cinnabar deposition overlap. However, whether calcite had any effect on the deposition of cinnabar is unknown. The relationship suggests the solutions which deposited calcite were probably similar to

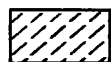
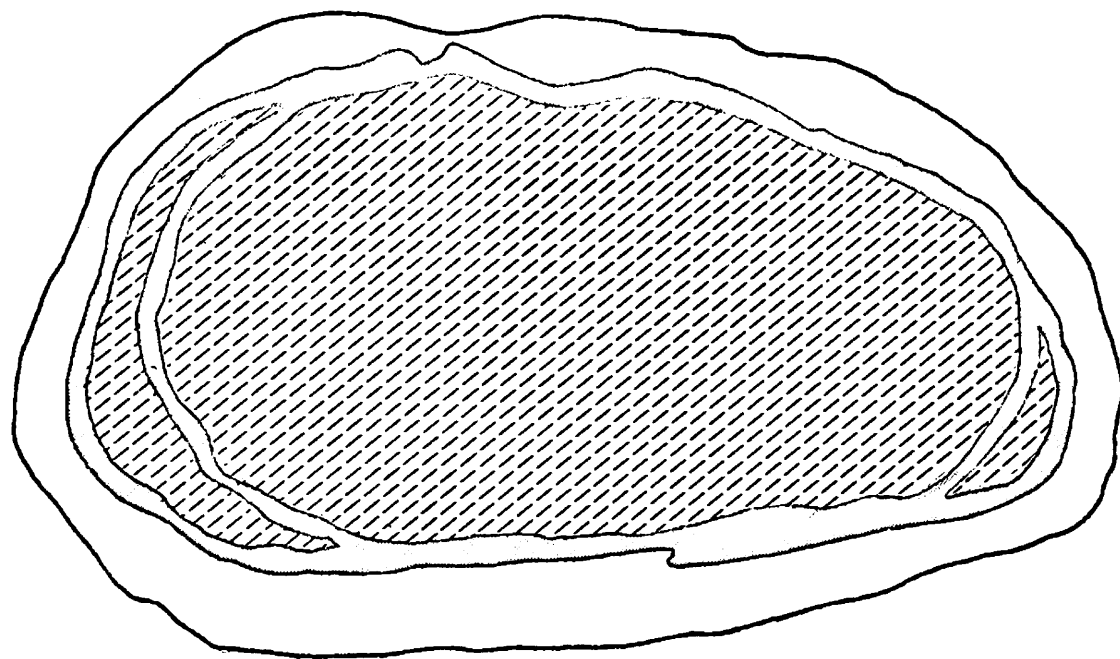


the solutions which deposited cinnabar and were at least weakly alkaline.

Extensive experimental information has been gathered in recent years on the solubility of cinnabar in aqueous sulfide solutions (Dickson, 1964; Barnes, Romberger and Stempok, 1967). Dickson concluded that some deposits have formed from alkaline aqueous sulfide solutions at comparatively low pressures and temperatures ranging from 100°C to about 230°C. The HgS is transported as the  $\text{HgS}^{2-}$  complex ion. Barnes, Romberger and Stempok have reached similar conclusions with the solutions being neutral to weakly alkaline.

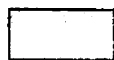
Another approach to solution composition came from examination of the concentric bands in tectonically brecciated andesite fragments (see figure 8 and plate 4a) from the 32 stope on the 1100 level, the only locale in the mine where they have been found.

Quartz-kaolinite makes up about 95 percent of the fragment pictured in figure 8, and these same minerals remain unchanged in all parts of the fragment. The carbonates are mainly siderite (varies from 0 to 5 percent, visual estimate) with a trace of calcite. The remaining minerals, with the exception of local concentrations, are present in trace quantity only.



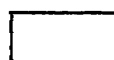
Inside of the Band

Siderite  
Calcite  
Disseminated HgS  
Pyrite  
Leucoxene



The reddish band

Finely dispersed  
hematite  
Carbonates (?)  
Local high HgS  
concentrations



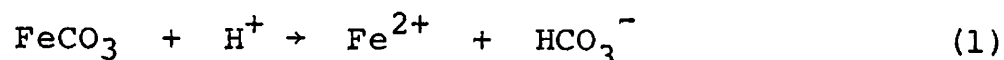
Outside of the band

No carbonates  
Pyrite  
Leucoxene  
Trace HgS

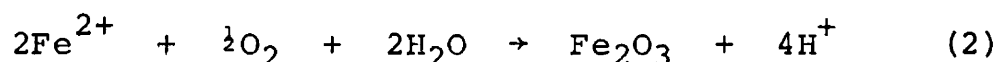
Figure 8. Sketch of the slabbed surface of an altered, brecciated andesite fragment (sample #1124) showing the inner zone where carbonates are stable, the very fine grained hematite band and the outer area where carbonates are not found. Actual specimen size is 5 inches by 9 inches.

As noted in figure 8, there are locally high concentrations of cinnabar in the reddish band, which was identified as fine hematite with the quartz-kaolinite (see 1100 East End Orebodies). Disseminated cinnabar is found inside the band and very sparsely outside of the band. Carbonates are stable inside of the band and have been removed outside of the band. The carbonates were present in very small quantities and were not distinguished within the reddish band.

The iron from siderite appears to have been leached from the outside of the band (figure 8) according to the suggested reaction in equation 1.



This reaction is pH dependent under conditions of 25°C and 1 atmosphere (Garrels and Christ, 1965). Iron would become appreciably soluble as the pH values decrease below 6. The other iron minerals could continue to be stable under these conditions. If the Eh or pH or both increased, then the iron that was present in the solutions could have precipitated as hematite (Garrels and Christ, 1965) according to the suggested reaction in equation 2.



No paragenetic relationships were detected between hematite and cinnabar. However, if mercury were being transported in the same solutions as the solutions which were leaching the iron, then the same reaction which deposited hematite could have precipitated cinnabar. Thus, it is suggested that solutions which transported mercury may have been acidic. This tends to be more in accord with White (1967), who does not believe there is strong enough support for a close association of mercury with high sulfide bearing alkaline solutions.

In conclusion, there is evidence for the transport of Hg in both alkaline and acidic solutions. Additional research is necessary in order to substantiate either of the transport methods.

Wall Rock Alteration. An indication of the overall chemical changes is reflected by the mineralogy of unaltered versus hydrothermally altered rocks. Basaltic andesite flows of the Fisher formation contain about 50 percent plagioclase, 22 percent clinopyroxene, 8 percent hypersthene, 13 percent magnetite and 7 percent partly devitrified brown glass (Hoover, 1963). The plagioclase normally is andesine (An 44-50). The andesite tuffs, though differing in mineralogy, probably are chemically similar. Hoover (1963) reports andesine in the tuff varying from An 32 to An 42.

The mineralogy produced by the hydrothermal alteration includes quartz, kaolinite, calcite, siderite and pyrite. The remaining minerals, including cinnabar, are present in trace quantities only. This mineralogic change is readily apparent, especially in the inner zone of silicification where the rocks are predominantly quartz with some kaolinite.

The first stage of alteration at Blackbutte, the quartz-kaolinite suite of minerals without any K-micas, suggests an assemblage of the advanced argillic alteration zone (Hemley and Jones, 1964; Meyer and Hemley, 1967) and indicates solutions had low cation to hydrogen ion ratios. This type of alteration is found as an inner or veinward zone of many

base-metal veins, telescoped pipes and porphyry copper deposits, as well as some shallow precious-metal veins in volcanic areas and in the more acid hot spring environments (Meyer and Hemley, 1967). Hydrolytic base leaching from all aluminous phases produces kaolinite, and when alumina is mobilized and removed, silica remains.

The apparently low cation/ $H^+$  solutions which produced the quartz-kaolinite would not be compatible with contemporaneous precipitation of carbonates. The solutions that deposited the carbonates would be expected to have moderate to high cation/ $H^+$  and at least a neutral to weakly alkaline pH. Reaction between low cation/ $H^+$  solutions and the country rocks involves loss of  $H^+$  from the solutions in exchange for  $K^+$ ,  $Na^+$ ,  $Ca^{2+}$ ,  $Mg^{2+}$  and  $Fe^{2+}$ . If these same solutions contain a constant total carbon species, a reduction in  $H^+$  by reaction with silicates results in an increase in  $CO_3^{2-}$  with respect to  $H^+$ , which could lead to precipitation of carbonates as suggested by Holland (1967).

The alteration mineralogy and the paragenetic sequence at the Blackbutte mine suggests initial solutions of low cation/ $H^+$  which were progressively depleted of  $H^+$  resulting in moderate to high cation/ $H^+$  with time. This facilitated later stage carbonate deposition and probably cinnabar deposition. The transition was gradual and sometimes even reversed indicated by instances of quartz-kaolinite overlapping some of the carbonates.

## Chapter 7

### SUGGESTED POTENTIAL EXPLORATION TARGETS

Production from the Blackbutte mine in the earlier years came from silicified rocks of the inner alteration zone along the sharp Black Butte fault on the upper levels of the mine. This is evident in the 200, 300 and 400 stopes. The mining in recent years has come from lower orebodies in weakly silicified rocks of the intermediate alteration zone. The Black Butte fault on the lower levels is no longer a sharp, regular feature but it has become a zone 200 feet or more in width as noted on the 1100 level, especially the east end. The ore in the intermediate zone is disseminated in usually soft, altered and bleached tuffs rather than its occurrence above in small veinlets in dense, hard silicified rocks.

There is no indication that mineralization has ended at the faces on the east end of the 900 and 1100 levels. It is suggested to continue above the 900 level and below the 1100 level. The eastern portions of the mine associated with the known mined areas are the suggested potential areas for additional mercury reserves. This area has been noted on plate 7 (back folder).

Mining on the Dennis Creek level (Waters, 1945) located mineralization on the projection of the Big stope. The area inbetween this and the 1100 level (500 feet) may be an area of extensive lower grade mineralization. This was suggested by mercury assays in the 1200 drift which usually ran 1.5 to 2 pounds per ton. This area has been noted on plate 8 (back folder). Easterly drifting on the Dennis Creek level is approximately 400 feet from the projection of the east end orebodies.

The Black Butte fault deviates from a linear feature, such as the curvature (3 to 5 degrees) and offset (10 to 15 feet) as shown on plate 7 between the 400 level and the 400 sublevel to the west. A similar change in strike was noted above the 300 level on the west end (not shown on map). Possibly through these points, a fault with a small displacement cuts across the Black Butte fault. A line along the Black Butte fault between these two points is relatively parallel to the plunge of the Big stope ore shoot. In addition, there are other examples or suggestions of offsets of the Black Butte fault. They include the fault at the east end of the Smoky stope on the 900 level and the change in fault trend on the 1100 level, west end.

Perhaps the above mentioned small offsets of the Black Butte fault have exerted some control on the mineralization.

If this is the case, then an understanding of the number and nature of these offsets may locate similar trends which could be potential targets for ore shoots similar to the Big stope.



## Chapter 8

### CONCLUSIONS

The Blackbutte mercury mine is located in a heterogeneous sequence of lava flows and pyroclastics of the Fisher formation. The mineralization occurs along and adjacent to the Black Butte fault which outcrops along the crest of Black Butte. The fault trace is marked by prominent silicified ribs. The fault appears more continuous on the upper levels of the mine but becomes more irregular in both strike and dip on the 900 and lower levels. It also appears to be a fault zone 200 feet or more in width on the lower levels.

Hydrothermal solutions of varying composition came up along the fault and altered to varying degrees all rocks which now form the present Black Butte. The major hypogene minerals are quartz, kaolinite, siderite, calcite, and pyrite. Minor sulfides which previously had not been reported at Blackbutte include mercurian tetrahedrite, sphalerite, chalcopyrite and arsenopyrite. Following deposition of most of the non-sulfide minerals and the iron sulfides, mercurian tetrahedrite, sphalerite, and chalcopyrite were

deposited. Emplacement of cinnabar occurred last in the cycle in open spaces in weakly silicified, very porous tuff units and in brecciated, silicified rocks. It occurs as disseminated grains in the tuff and short discontinuous veinlets and blebs in the brecciated, silicified rocks. Replacement of earlier minerals by cinnabar is minor. The orebodies in the tuffs have very irregular boundaries and are generally pod shaped.

Hydrothermal zoning in the accessible underground workings is evidenced by textural and mineralogic variations. Three zones, an outer, an intermediate and an inner zone have been proposed. Relict textures are discernable except in the inner zone of silicification. The fine grained quartz produced by the alteration generally increases in grain size with increasing intensity of alteration. Siderite is leached in the intermediate zone but was deposited later in the hydrothermal cycle in brecciated, silicified rocks of the inner zone. Later stage calcite varies from disseminated grains in the outer zone to large veins in the inner zone. The cinnabar found in the tuffs is in the intermediate alteration zone and the cinnabar in brecciated, silicified rocks is in the inner alteration zone.

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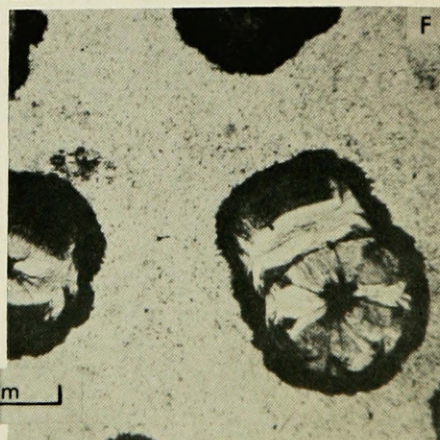
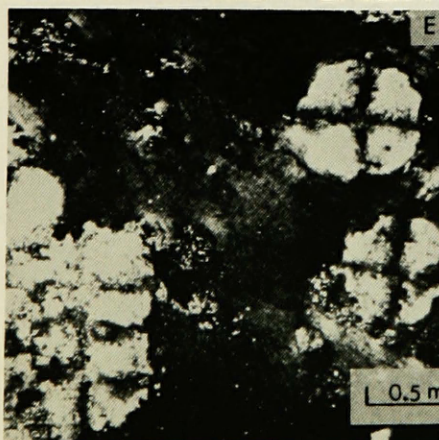
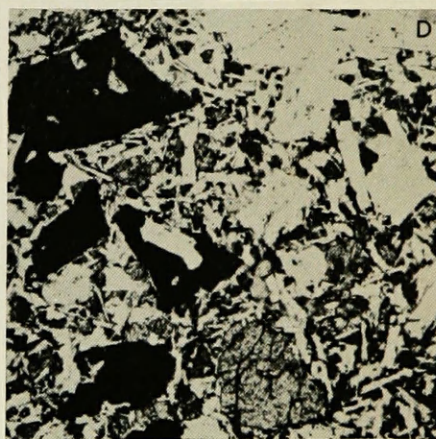
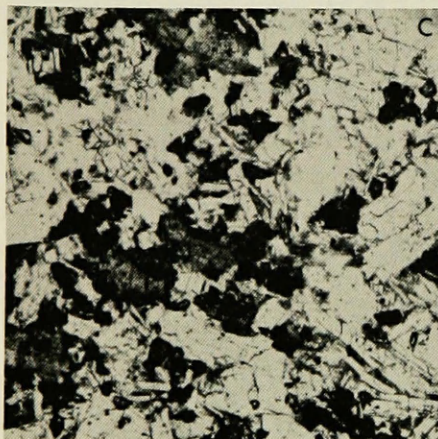
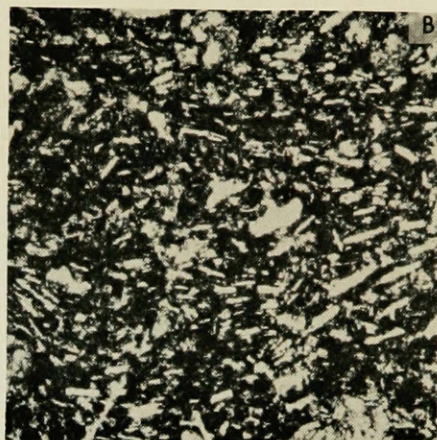
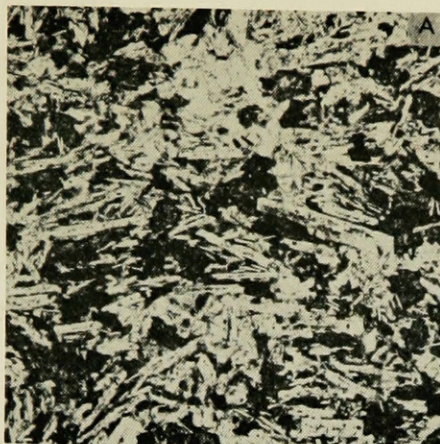
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## APPENDIX

## PLATE 1

- a. Photomicrograph. (#FF-1) Fisher formation, unaltered andesite flow. Subparallel laths are plagioclase. Dark grains are clinopyroxene and some opagues.
- b. Photomicrograph. (#1199) 1100 level, unbleached andesite (outer zone). Plagioclase almost completely altered to fine grained quartz-kaolinite. Dark material is carbonate and iron opagues. Note relict texture similarity to a. above.
- c. Photomicrograph. (#FF-2) Fisher formation, unaltered andesite flow. White grains are plagioclase. Darker grains are pyroxene which has been partially weathered.
- d. Photomicrograph. (#1197) bleached andesite (outer zone). White phenocrysts are relict plagioclase which has been altered to fine grained quartz-kaolinite, black euhedral grains are siderite and gray anhedral grains are calcite. Quartz-kaolinite also forms part of the matrix surrounding the relict phenocrysts. Note relict texture similarity to c. above.
- e. Photomicrograph. (#1170) 1100 level, weakly bleached tuff (outer zone). Spherulites are fine grained siderite (under x-nicols). Dark groundmass is quartz-kaolinite.
- f. Photomicrograph. (#11131) 1100 level, recrystallized (?) spherulites in a groundmass of fine grained quartz-kaolinite.

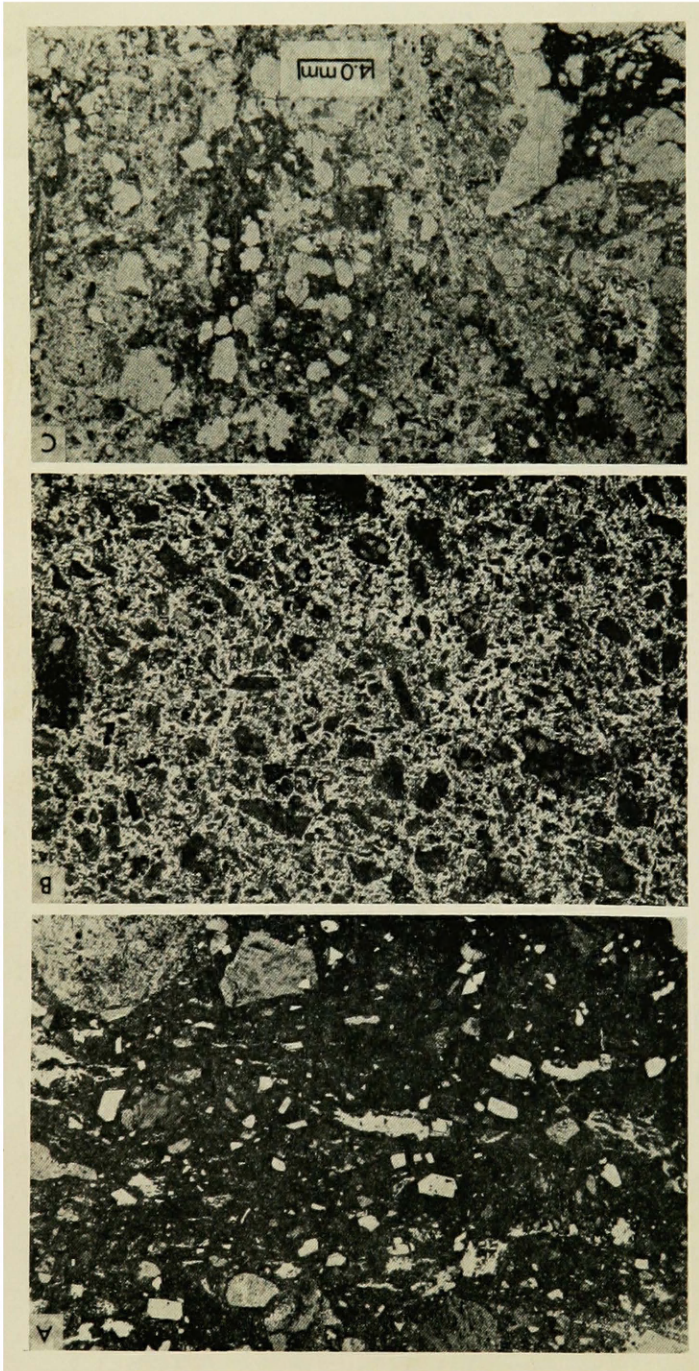


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## PLATE 2

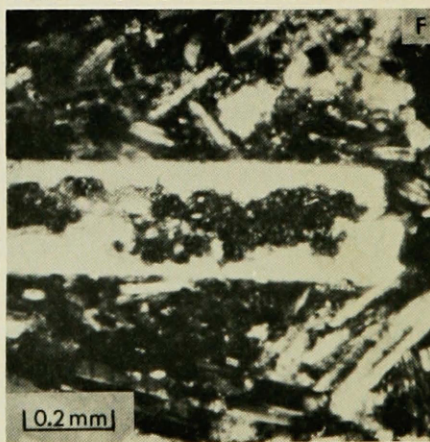
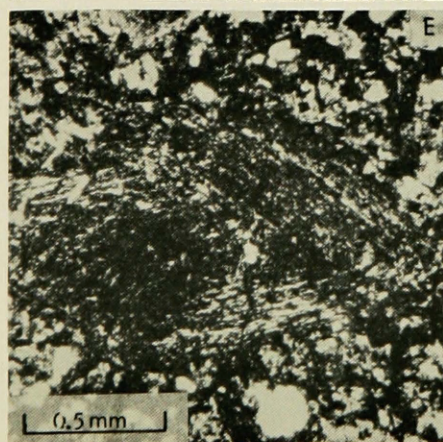
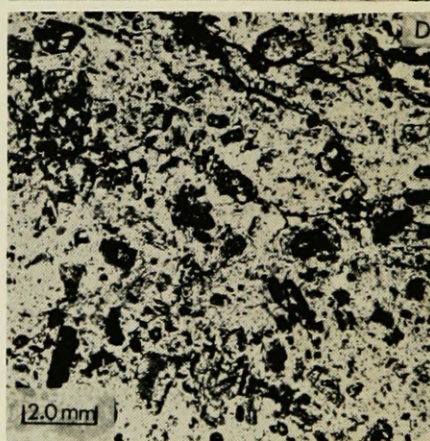
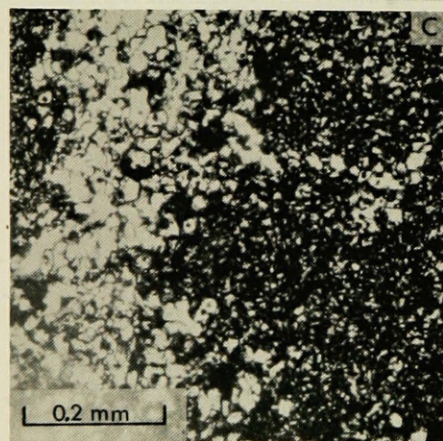
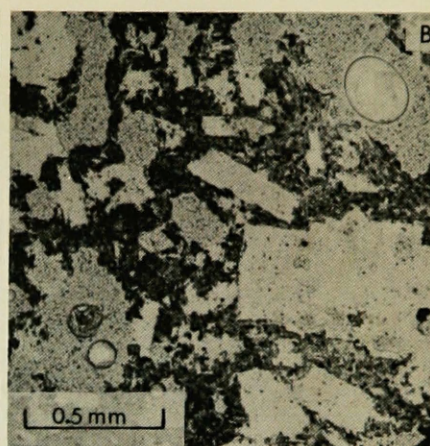
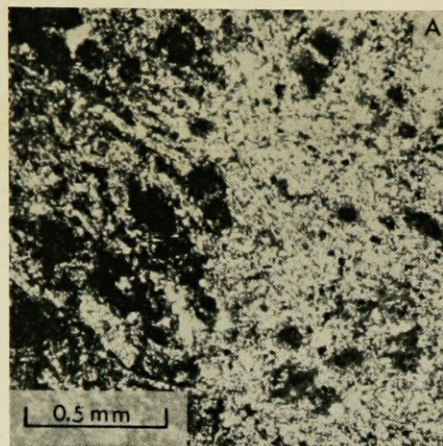
- a. Photomicrograph. (#FF-3) Fisher formation, unaltered crystal tuff. Crystals are plagioclase.
- b. Photomicrograph. (#1181) 1100 level, altered and bleached crystal tuff (intermediate zone). The rock consists of a mass of fine grained quartz-kaolinite. Dark spots are holes in the slide. Note relict texture similarity to a. above.
- c. Photomicrograph. (#1224) 1200 level, silicified tuff (inner zone). Entire rock is a fine grained mass of quartz and some kaolinite with a limonite (supergene) stain. Dark material in lower corner is siderite. Note relict texture similarity to a. above.



### PLATE 3

- a. Photomicrograph. (#11140) 1100 level, brown andesite with a discolored or bleached band (outer zone). Dark grains are siderite. White is quartz-kaolinite and gray material is calcite. Bleaching has occurred (a relict texture is continuous across the slide) on the right half of the photograph where it appears as though siderite was being leached as suggested by its incomplete removal.
- b. Photomicrograph. (#1124a) 1100 level, 32 stope, altered andesite (intermediate zone). White relict phenocrysts have been altered to fine grained quartz-kaolinite. Darker material is quartz-kaolinite mixed with carbonates and pyrite. The iron minerals (mostly siderite) have been altered to hematite in the left half of the photograph. Oval features are bubbles in the slide.
- c. Photomicrograph. (#1224) 1200 level, fine grained quartz-kaolinite (inner zone). Finer grains are predominantly kaolinite. Larger grains are predominantly quartz.
- d. Photomicrograph. (#1280) 1200 level, silicified (inner zone). Sample is from an area adjacent to a calcite vein. The euhedral calcite grains and the even distribution of very fine opagues through both the quartz and calcite suggests calcite (darker grains with higher relief) has replaced some quartz.
- e. Photomicrograph. (#1197) 1100 level, partially altered, zoned plagioclase phenocryst. Kaolinite has formed along zone boundaries.
- f. Photomicrograph. (#1249) 1200 level, twinned plagioclase phenocryst. Kaolinite has formed along the twin boundary.

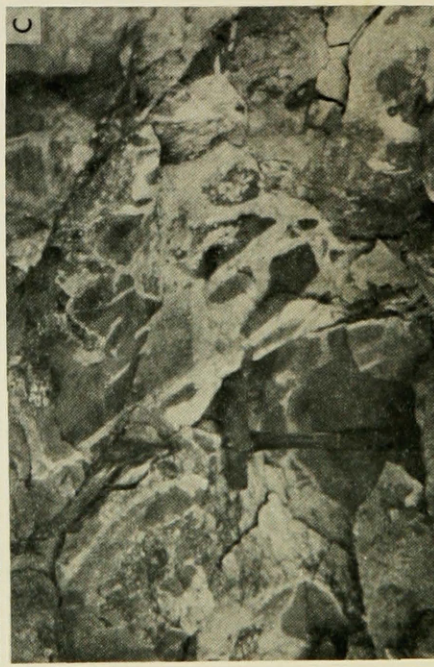
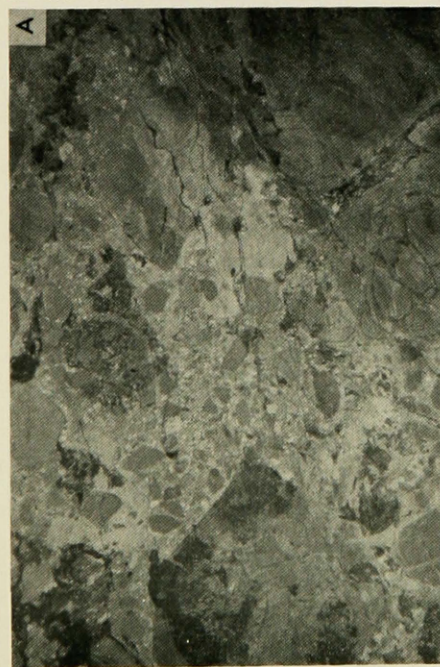
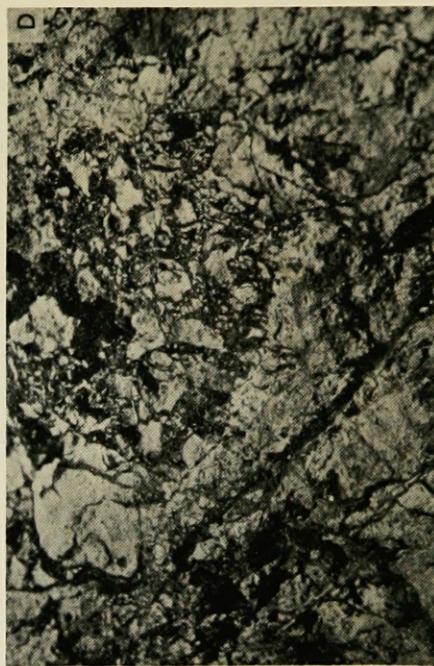
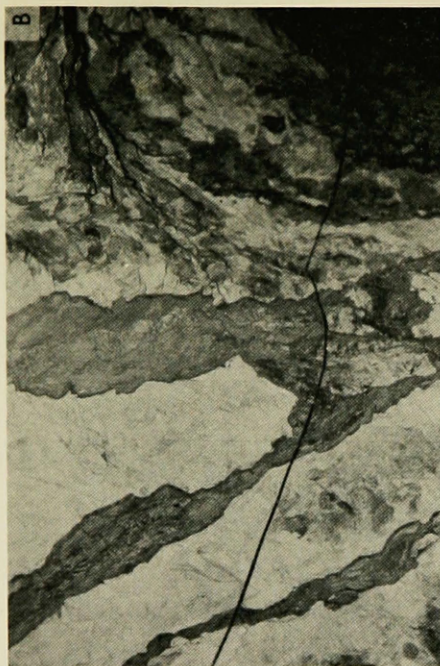




#### PLATE 4

- a. Mine Exposure. 1100 level, 32 stope, brecciated andesite. Note rings or concentric bands in the lower center of photo. They are concentrations of finely dispersed hematite from alteration of siderite. Fresh siderite remains in the center of the rings suggesting the alteration was not complete. Width of the exposure in the photo is approximately 6 feet.
- b. Mine Exposure. 1100 level, below the Big stope. Secondary limonite (darker seams in the left half of photo) in yellow-brown stained kaolinite (white). These are common in the fault zone in the vicinity of the Big stope.
- c. Surface Outcrop. On the mine road near the 1100 portal. Brecciated andesite accentuated by bleaching or discoloration along fractures.
- d. Surface Outcrop. Located at the top of Black Butte. A silicified rib. The rock was later brecciated and recemented by siderite (black). Width of the outcrop in the photo is approximately 2 feet.

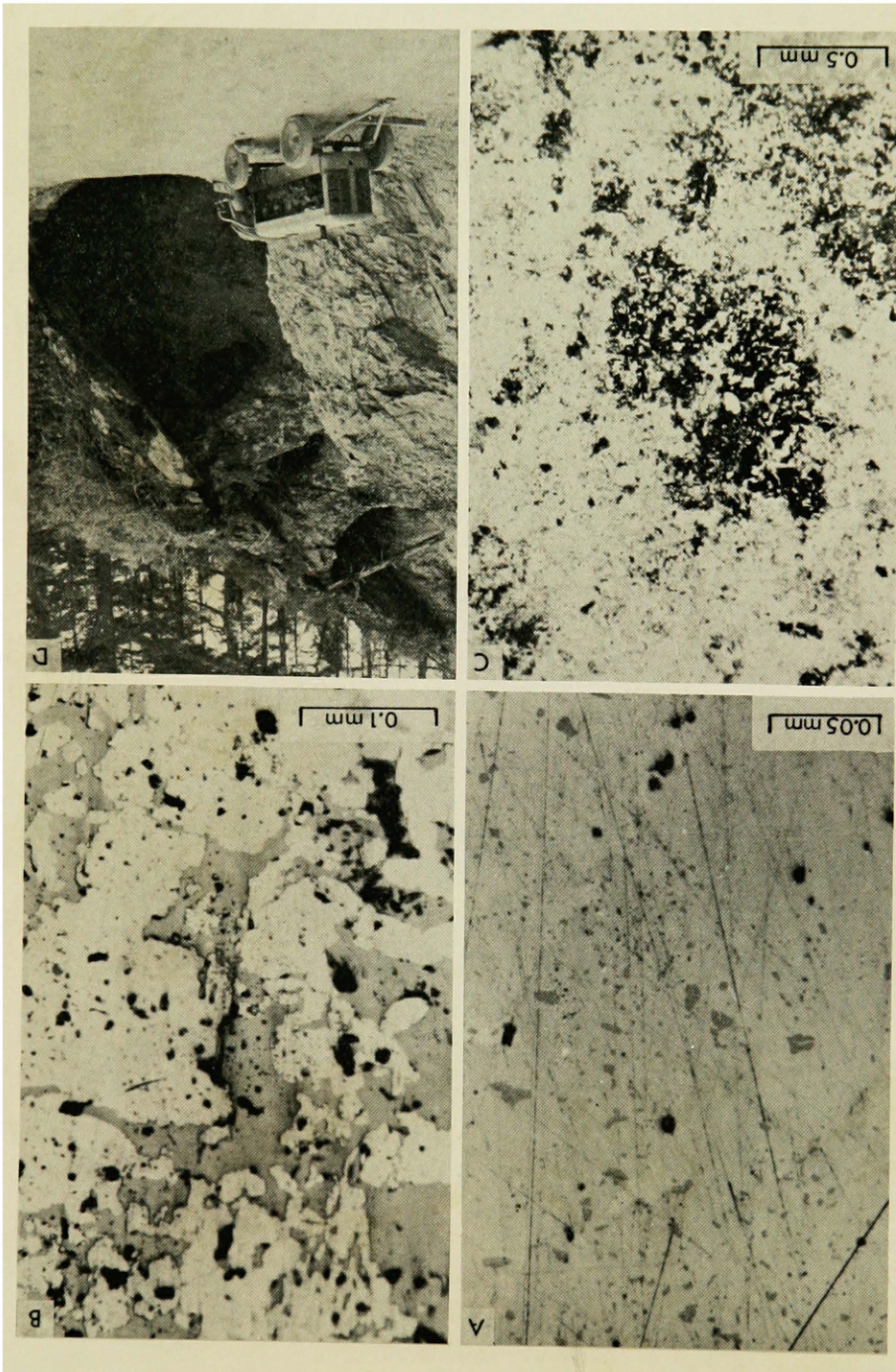




## PLATE 5

- a. Photomicrograph. (polished section BB-2), 900 level. Small blebs of sphalerite (dark gray) in cinnabar (medium gray). Lighter gray, irregular grains at top center and right center edge of photo are tetrahedrite. Small white blebs are chalcopyrite. (Note cinnabar veinlet cutting sphalerite at left center of photo.) Black spots are holes and lines are scratches.
- b. Photomicrograph. (polished section BB-11), 200 level. Secondary goethite (dark gray) replacing cinnabar (light gray). Black spots are pits in the section.
- c. Photomicrograph. (thin section #1246), 1200 level, andesite tuff. Magnetite (black) in fine grained quartz-kaolinite. Magnetite localization may be due to alteration of a ferro-magnesian mineral.
- d. Stope with supporting pillars remaining, located between the 200 and 300 levels, west end of the mine. Note the single, sharp bounding fault below which the ore was found.

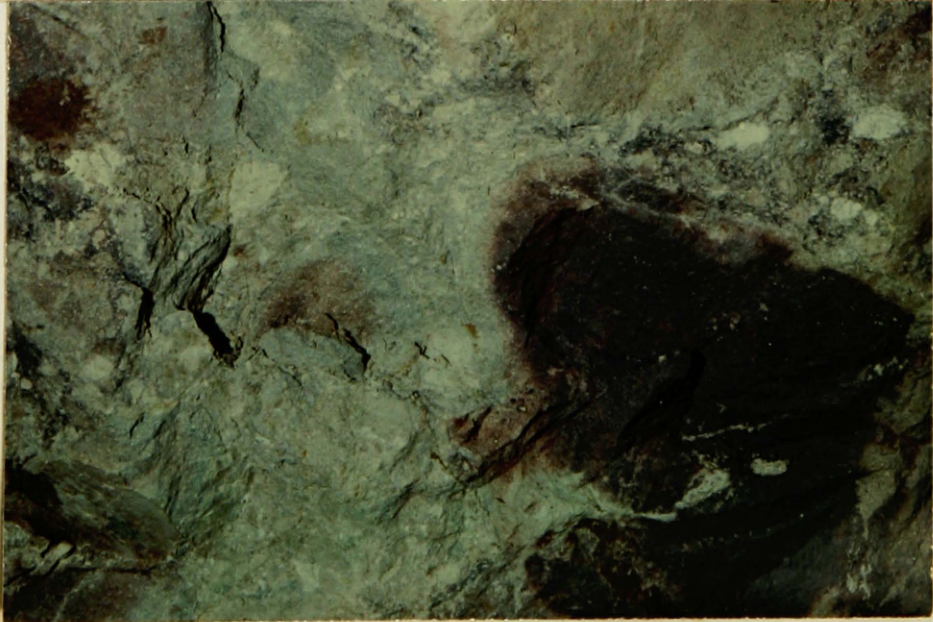
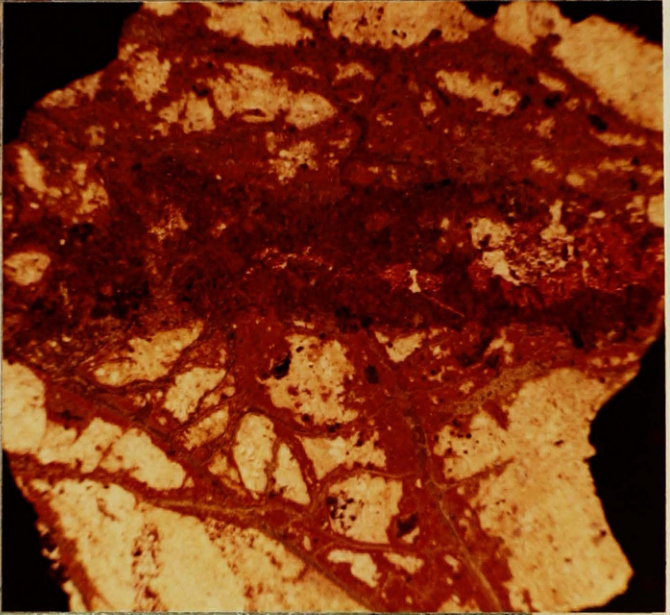
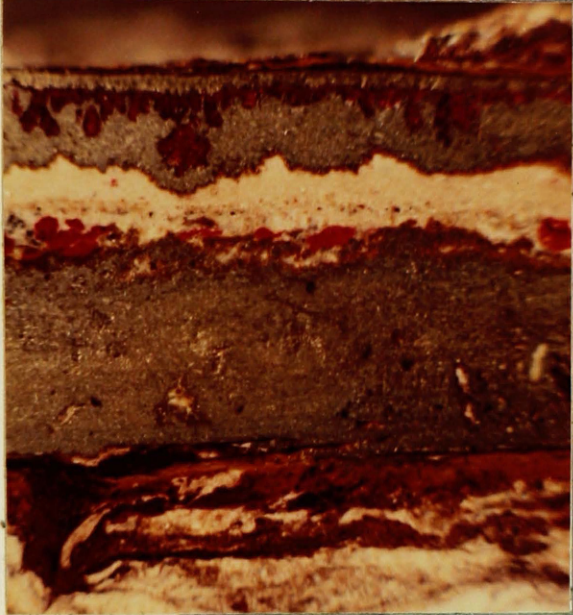
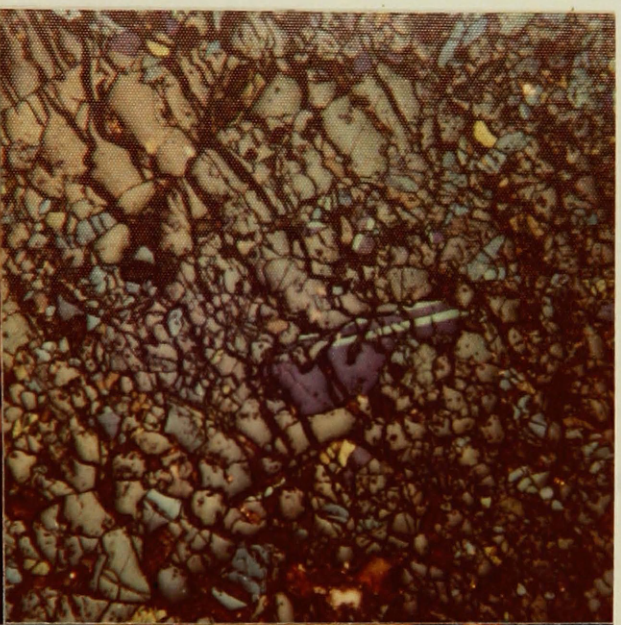
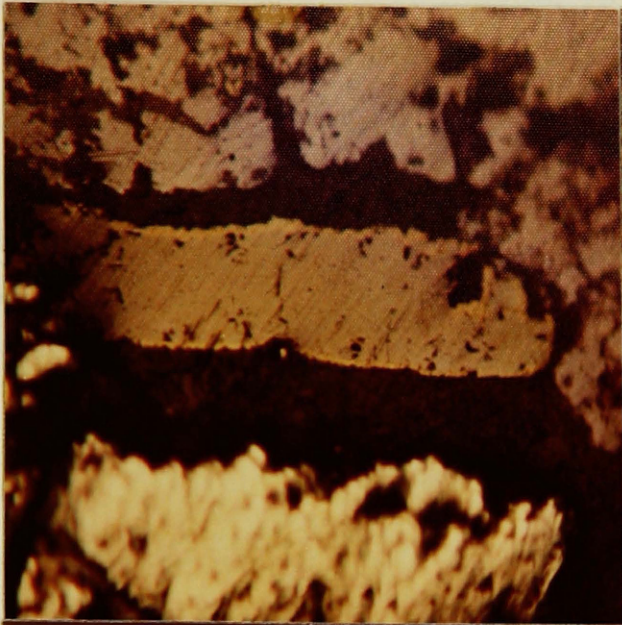






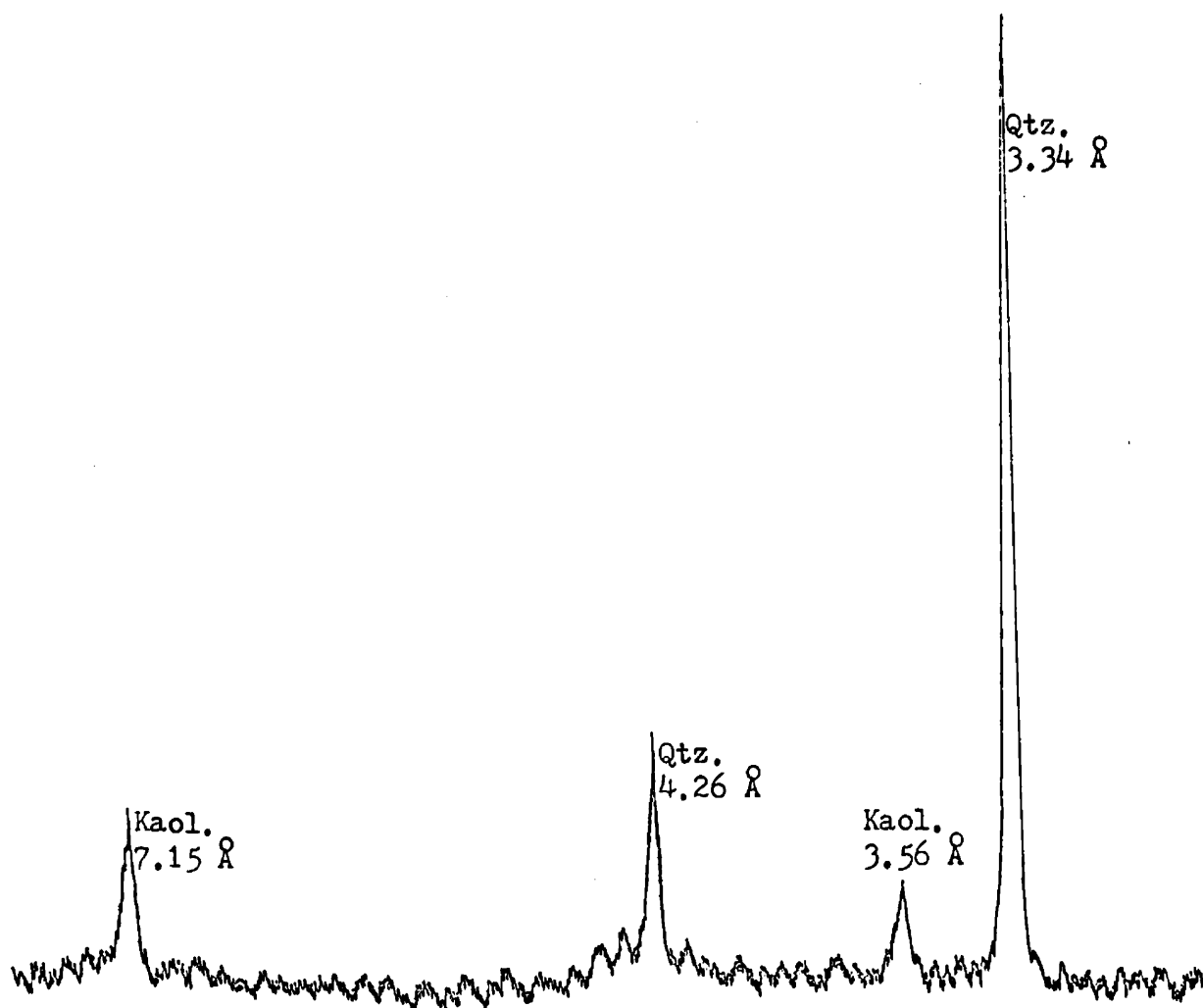
## PLATE 6

- a. Photomicrograph. (polished section BB-8), 1200 level. Tetrahedrite in the center of the photo rimmed by chalcopyrite.
- b. Photomicrograph. (polished section BB-1), 1100 level. Marcasite (blue, brown and yellow) and pyrite (gray). Note the twinned arsenopyrite near the center of the photo. (under crossed nicols).
- c. Microphotograph. (polished surface BB-1), 1100 level. Massive pyrite-arsenopyrite veinlet with later quartz-kaolinite (white) and cinnabar (red). Note cinnabar filling fracture and also replacing iron sulfides in one direction away from the fracture. Width of sample in the photo is 0.6 inches.
- d. Microphotograph. (polished surface BB-12), 200 level. Later cinnabar veinlet cutting smaller pyrite veinlets. Tan material is quartz-kaolinite. Note limonite halos around small pyrite veinlets. Width of the sample in the photo is 1.0 inches.
- e. Microphotograph. Mine exposure, 1100 level, east end. Incompletely bleached pod (dark brown) in an andesite tuff.

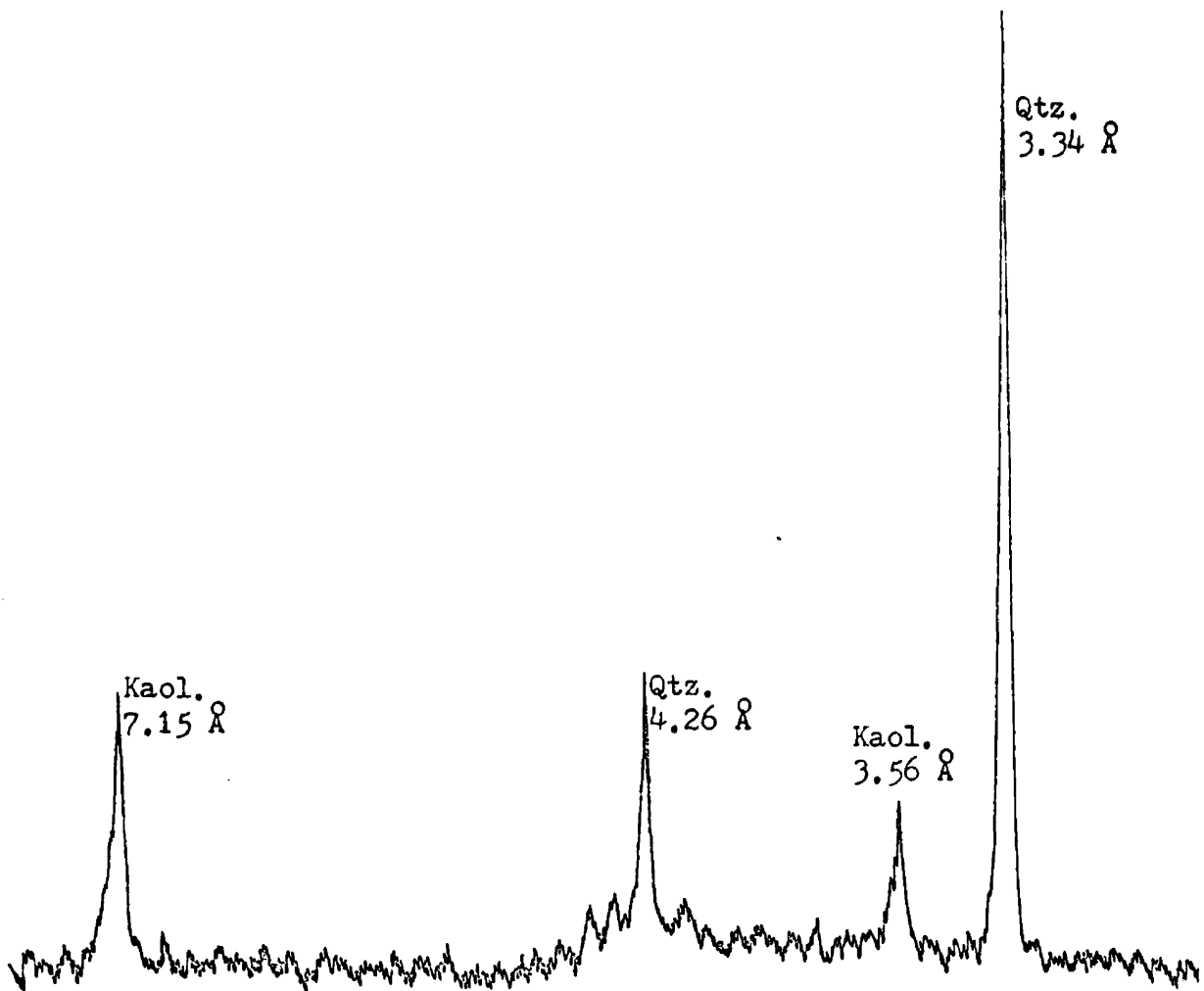


## QUARTZ/KAOLINITE X-RAY PEAK INTENSITIES

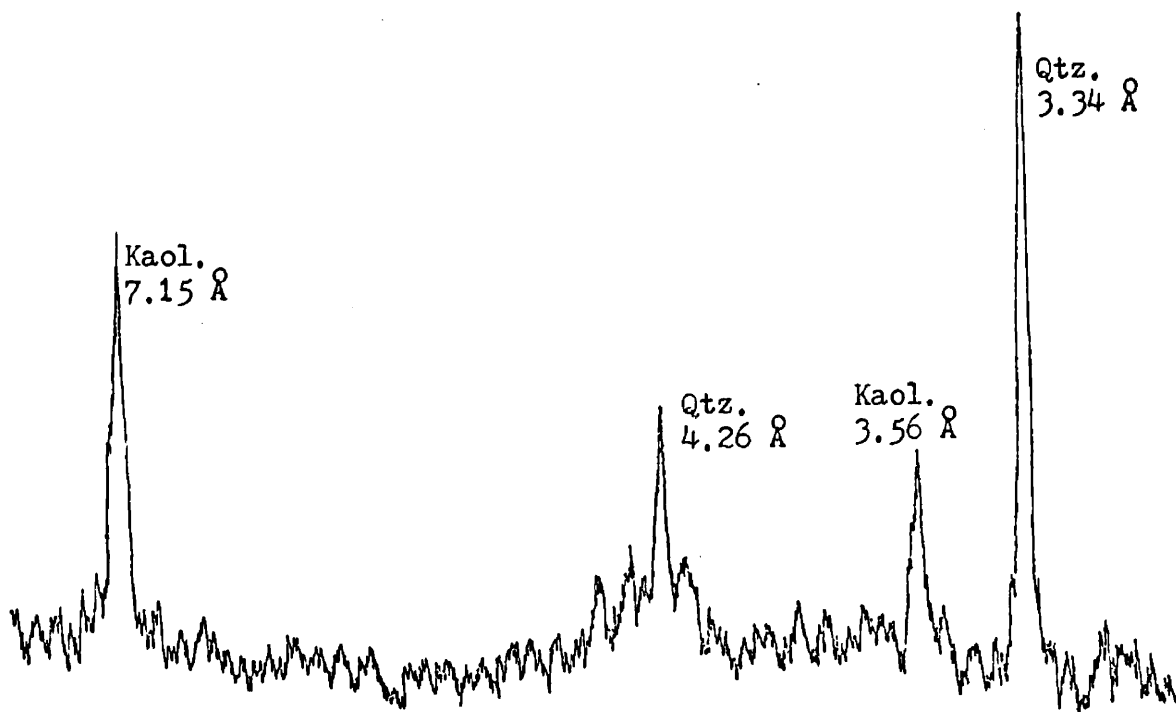
The following are three x-ray diffraction patterns representing whole rock scans from  $30^\circ$  to  $10^\circ$  of samples from each of the three hydrothermal zones. Intensity ratios of the  $3.34 \text{ \AA}$  peak of quartz verses the  $7.15 \text{ \AA}$  peak of kaolinite were calculated for each sample. The additional peak at  $4.26 \text{ \AA}$  is quartz and the peak at  $3.56 \text{ \AA}$  is kaolinite.



A. Inner zone (#1222). Quartz/Kaolinite = 5.50



B. Intermediate zone (#1270). Quartz/Kaolinite = 3.50.



C. Outer zone (#1155). Quartz/Kaolinite = 1.54.